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Swastika Forest Station
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CONTAINER STOCK PRODUCTION
NORTHERN REGION

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Since the late 1960's, the Ministry of Natural Resources' Northern Region has been producing containerized tree seedlings at the Swastika Forest Station. The Ontario tube was the main container used until the late 1970's. Since then the Japanese paperpot has been adopted as the primary container. Total production in the past has been in the 4 million to 6 million range annually.

The Forest Management Agreement (FMA) became the new approach to Ontario forestry in the late 1970's and early 1980's. These agreements include the Ministry's responsibility to provide planting stock to all FMA holders. As a result of this commitment the region's forecast of planting stock requirements taken in 1981 projected a 30 million tree increase for the 1984 planting season.

In order to provide this stock to the client groups in such a short period of time the region decided to produce this increased requirement by accelerating the container stock production programme through the private sector.

A greenhouse can be constructed in almost any location, requires very little space and can be in production in less than 12 months. Container

stock can also extend the planting season; hand planting productivity is higher and it has a higher percent of seed utilization. Therefore, in 1981 the task before this region was to increase the supply of container stock gradually to annual totals of 8 million in 1982, 18 million in 1983 and 33 million in 1984.

This region had some experience with private greenhouse growers since 1979 but there was actually nothing available in the area that would produce this large volume of stock.

In the summer of 1981 advertisements were placed in the newspapers across the region calling for proposals for seedling production. Through the Ontario Board of Industrial Leadership and Development (B.I.L.D.) capital funding was made available to cover 50% of the initial construction costs. Each successful proponent would also receive a five year growing contract with the selling price negotiated annually. The Crown would also provide overwintering material, seedling trays and arrange the shipping of trees from the contractor's premise to the field planting locations.

The response from the private sector was overwhelming and resulted in 10 greenhouse complexes being constructed in late 1981 and the summer of 1982 (Table 1).

Since our demand figures at the time called for more trees available for planting in the spring than the summer, the construction of one-crop quonset greenhouses was not discouraged. Today, approximately 65% of all the production is overwintered material and 35% is current production.

The one-crop quonset system produces a large size one-year seedling for spring planting. Seeding takes place in late April to early May with removal from the greenhouse in October for overwintering at the contractor's site. The seedlings are available for shipping to the planting site the following spring.

The double-crop system requires a gutter-connected style of greenhouse or well insulated quonset. The main objective of the gutter-connected style is to reduce heat loss with a common wall.

This type of facility will produce a medium to large current-growth seedling for planting after mid-June. Seeding takes place in mid-January for Sb and mid to late February for Pj. The current crop is removed from the greenhouse by mid to late May and conditioned outside in the holding area.

After removal from the greenhouse a second crop is seeded which will produce a small to medium grade seedling for next spring planting. These seedlings are removed from the greenhouse in October and overwintered in the holding area. Table 2 shows the type of seedlings produced by using the two types of production systems.

The growing agreement has minimum standards of 10 cm height and 300 mg dry weight. The region plans to increase these standards as the experience and techniques improve. This major increase in production in such a short time frame is in many ways a success story but it is not without its problems and drawbacks.

The expertise available to the private contractor in the form of competent staff was, and still is, lacking. Although a few of the contractors themselves had experience in greenhouse production, the majority were businessmen with no practical experience in this type of work. The region helped as much as physically possible but since some of the techniques of stock production are not as yet perfected, a void has developed in the training of employees.

This has led to major problems in the following areas: peat moss types and compaction, seeding, germination, heating, overwintering, trees leaning towards light, water patterns, premature bud set, heat stress, water stress and inventory.

The inventory of shippable trees in paperpots is one of the major problems. For example, if a tray of large Sb containers has a stocking of 311 trees per tray (92%), then that means that 311 trees in this tray meet or exceed the minimum height of 10 cm. When the tray is taken apart it is discovered that there are actually 304 trees in the tray and only 300 trees (89%) exceeded the minimum height standard and 4 trees were below the minimum height standard. This may seem like a small difference but 11 trees short per tray on 7,000 trays is 77,000 trees.

The next example is a tray classified as a shippable tray with 301 trees. When taken apart, there was a total of 294 trees of which only 205 trees exceeded the minimum height standard.

This is one of the major problems. Poor inventories can cause major problems through the entire system, from the planning and allocation stage right down to the planting contractor.

With a projected production approaching 50 million by the late 1980's the region's main effort will now be to improve the quality and reliability of seedlings produced.

Hopefully, in the next 2 years, a book of growing and handling guidelines can be put together for Provincial use.

In summary, the last 30 months have seen the Northern Region's production increase from 5 million to 33 million. The quantity objective has been achieved, now the quality is the next target.

Table 1. Private greenhouse contractors - Northern Region - 1982

Contractor	Location	Greenhouse type	Total square feet	Production (000's)
Aidie Creek	Englehart	Quonset (SC)*	31,104	1,935
North Gro	Kenogami	Quonset (SC)	31,104	1,935
Blazecka	Cochrane	Quonset (SC)	16,160	800
Birchill	Cochrane	Quonset (SC)	31,104	1,935
Millson	Val Gagne	Quonset (DC)**	17,280	1,816
Lava Mountain	Ramore	Gutters (DC)	32,120	4,000
Energreen	Ramore	Gutters (DC)	50,400	6,400
Northern G.F.	Iroquois Falls	Gutters (DC)	27,728	3,568
Lafleur Gardens	Timmins	Gutters (DC)	23,520	3,226
La Maison Verte	Hearst	Gutters (DC)	16,416	1,930
TOTAL			277,936	27,545

*SC = Single Crop
**DC = Double Crop

Table 2. Type of black spruce seedlings produced - 1983

Production system	Crop type	Height (cm)	Diameter (mm)	Dry weight (mg)
Double Crop	Current	19.7	1.91	618
Double Crop	Current	19.0	1.90	655
Double Crop	Current	19.2	1.60	515
Double Crop	O.W.*	14.8	1.73	515
Double Crop	O.W.	15.6	1.57	461
Double Crop	O.W.	13.4	1.64	423
Double Crop	O.W.	14.5	1.71	464
Single Crop	O.W.	23.9	2.07	873
Single Crop	O.W.	20.3	1.93	793
Single Crop	O.W.	16.8	2.21	841

*O.W. = Overwintered

ROOT PRUNING AND ROOT WRENCHING

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Introduction

Root pruning (undercutting) and wrenching have been carried out in New Zealand for over fifty years, van Dorsser and Rook (1972). There are many claims regarding the benefits of these procedures. Ritchie and Dunlap (1980) make the following claims:

1. Causes early cessation of top growth.
2. Induces dormancy.
3. Improves aeration of the seedbed.
4. Increases root fibrosity.
5. Improves Root/Shoot balance.
6. Dramatically increases root growth potential - up to 10 times in Carribean pine (Pinus caribaea Mortlet), with similar results in Radiata pine (Pinus radiata D. Don.) and Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco].

van Dorsser and Rook (1972) make the following claims:

1. Pruned and wrenched seedlings are better able to withstand root exposure than are unwrenched stock.
2. Pruned and wrenched seedlings are able to withstand higher temperatures during transportation than are unwrenched stock.
3. Pruned and wrenched seedlings are able to withstand cold storage better than unwrenched stock.
4. Pruned and wrenched seedlings survive at a higher rate and grow better than do unwrenched stock.

5. Seedlings can be conditioned for outplanting at anytime of the year by proper timing of the sowing date and the beginning of the pruning and wrenching treatments.

Root pruning or undercutting, consists of drawing a sharp blade under the seed bed, at a depth of 5 to 8 cm, to sever the tap root. For this operation soil moisture conditions should be fairly high, close to field capacity, so that the seedling root system is held firmly in the soil, allowing the tap root to be cut cleanly. A reciprocating pruning blade is recommended and it should be drawn through the soil at as flat an angle as possible so as not to disturb the lateral roots.

Root wrenching consists of drawing a blade, set at an angle, through the soil, below the pruning cut. This action breaks off any deeply penetrating roots and lifts the soil and the seedlings, dropping them over the back edge of the blade, as it is pulled through the soil. This action aerates the soil and disturbs the contact between the soil particles and the seedlings roots.

The root pruning and wrenching operations should be started at least 10 to 12 weeks before the seedlings are to be outplanted. Wrenching is carried out at weekly, bi-weekly or monthly intervals depending on the nursery and the type of planting stock required. Vertical root pruning is carried out at 4 to 6 week intervals to control lateral root development.

According to van Dorsser and Rook (1972), these operations have been carried out on beds of radiata pine varying in density from seedlings 1.25 to 6.5 cm apart in the rows, with the rows 17.5 cm apart (88 to 457/m^2), without affecting height growth. However, the lower densities did produce heavier seedlings with an improved root fibre. They state that it is most important that the seedlings be pruned as shallowly as possible and that densities be thin enough (160 to 215/m^2-my estimate) so that the seedlings are able to respond to the pruning and wrenching treatment. In other words if seedbed densities are too high the height of the seedling, after treatment, may not be affected, but other responses, particularly root fibre development, will be less than expected.

After wrenching the radiata pine seedlings often take on a chlorotic appearance. Additions of nitrogen to the soil prior to the pruning and wrenching operations will reduce or eliminate this colour change and lead to an increase in nitrogen reserves, especially in the roots, without affecting the results of the treatments. They further state that to maximize the pruning and wrenching effects, the treatments are best applied in very fertile soils when vigorous growth is taking place.

It seemed to us, at Orono, that the results of the New Zealand technique, a) improved survival and growth, b) increase in root fibrosity, c) increase in Root Growth Potential (RGP) and d) increase in survival after cold storage, might be beneficial in solving, what in Ontario has become known as the red pine (Pinus resinosa Ait.) problem, the inability of red pine to regenerate roots quickly after out planting, and secondly the high degree of variation in the survival of red pine after overwinter frozen storage.

While there are differences in the times required to produce radiata pine and red pine, one season for radiata in New Zealand, and three years for our red pine, it was hoped that ways around this difference could be found. van Dorsser and Rook (1972), state that seedlings may be maintained in a conditioned state for periods of up to several months, if necessary, by continued wrenching. It was decided to try this approach on red pine.

Since 1980 we have conducted four trials containing various combinations of the New Zealand treatments. The purpose of this paper is to summarize this work listing our accomplishments and recommending how we feel this valuable technique should be applied.

Nursery Trials

1. 1980 - The aim of this trial was to see if we could condition 3+0 red pine, by root pruning and wrenching, to improve its survival and growth, after fall lifting and overwinter frozen storage. A secondary aim was to see if the conditioning procedure would allow the seedlings to be lifted earlier in the fall than normal and still get satisfactory growth and

survival. This trial is fully reported in Nursery Note No. 99.

We had ordered a reciprocating root pruner to use in this trial, but it had not arrived when treatments had to be started, so our old passive root pruner was used, at a depth of 10 to 15 cm since we could not keep the blade in the ground at shallower depths.

We chose four treatments:

1. Early - Seedlings which received a root pruning in mid-April at 10 to 15 cm.
2. Normal - Seedlings which received a root pruning in mid-April at 10 to 15 cm and again on July 7th, our normal treatment for red pine.
3. 6 week - Seedlings which received a root pruning in mid-April at 10 to 15 cm and again on May 26th and then were root wrenched every 6 weeks to the end of September (3 wrenches).
4. 3 week - Seedlings which received a root pruning in mid-April at 10 to 15 cm and again on May 26th and then were root wrenched every 3 weeks to mid-October (6 wrenches).

Stock was lifted and placed in frozen storage, at weekly intervals, beginning on October 27th, two weeks earlier than our normal lifting time. The last lift was made on November 24th. On November 18th, the fourth lift, the soil was frozen and this sample was taken by breaking through the frost with picks and bringing the trees and frozen soil into the laboratory to thaw out. We did a great deal of root damage in securing this sample and feel the poor performance of the stock can be traced to this harsh treatment.

The trees were packed in multi-walled paper bags with a 2 mil poly-liner and stored at -2°C to -4°C until early April when the temperature was raised to 0°C to 1°C. Planting was done on April 22, 1981, along with "Fresh" lifted stock from the "Normal" treatment. Results are summarized in Tables 1 to 3.

Basically, by pruning at the 10 to 15 cm depth and then wrenching, we were not able to significantly reduce the size of this 3+0 red pine except for Total Dry Weight (TDW), of the "3 week" treatment (Table 1).

We were able to improve the storability of the red pine however. When comparing the "3 week" with the "Normal" treatment, we find that the "3 week" had significantly better survival on the first, and last lifts and better, but not significantly so, on the rest (Table 2).

In comparing the "3 week" and the "Fresh" treatments the "3 week" treatment was better on the October 27, November 3rd, and November 24th lifts, although significantly so only on the last lift (Table 2). These data indicate that we were able by pruning and wrenching, much deeper than recommended, to condition red pine so that it could be lifted for overwinter frozen storage at least a week earlier than normal. This is quite an important consideration when one is trying to lift for fall frozen storage and freeze-up is fast approaching.

Current height growth, after outplanting, was affected by treatment with the "3 week" producing the poorest growth. However these differences disappear by the third season (Table 3).

In summary, we feel, this trial shows that while we were not able to affect the size of the stock by pruning and wrenching, we were able to condition the stock for early overwinter frozen storage and to improve the survival of the treated stock over that of the "Normally" treated stock. Current height growth, after planting, was at first reduced by pruning and wrenching, but these differences disappeared during the third year. We feel that this sacrifice of a few centimetres of height growth is a very fair trade-off for the ability to lift earlier in the fall and the increased survival of the pruned and wrenched stock.

2. 1981 - The aim of our second trial was to see, if by shallow pruning in the 3+0 year, we could, a) decrease the size of our 3+0 red pine and b) determine what affect the treatments would have on the survival and growth after outplanting. This trial is fully described in Nursery Note No. 103.

We chose four treatments:

1. 3 week - Root pruned shallowly on April 27th and wrenched every three weeks from May to October (9 wrenches).
2. 6 week - Root pruned shallowly on April 27th and wrenched every six weeks from May to October (5 wrenches).
3. 1 wrench - Root pruned shallowly on April 27th and wrenched on May 5.
4. Control - No pruning or wrenching.

A "New Zealand" root pruner was used in this trial, however the size of 3+0 red pine roots made it impossible for us to prune at the recommended depth of 5 to 8 cm and pruning was carried out at a depth of from 7.5 to 10 cm.

Five replications from each treatment were lifted in November of 1981 to assess the effect on seedling size and a five replicated trial was outplanted on May 12th 1982.

We were able to affect the size of the final 3+0 product by pruning and wrenching (Table 4). Comparing the "3 week" treatment with the "Control" we were able to reduce the height by 14.4%, RCD by 15.2%, TDW by 51.4% and T/R by 70.4%. We were surprised that we got no significant change in RAI.

Survival after outplanting was not affected by treatment (Table 5). However 1982 was a very moist year (Figure 1) and "red pine problem" growth was again significantly reduced by the "3 week" and "6 week" treatments. However second year growth measurements showed that the trend had been reversed and the "3 week" treatment was significantly better than the rest.

In summary, pruning and wrenching did reduce all the seedling parameters measured except for RAI. Survival, in a wet spring, was not affected by treatment. Height growth of the most severely wrenched treatment was reduced in the first season after planting but in the second season produced the best growth.

3. 1981 - Our third trial was also started in 1981, using rising 2+0 red pine. The aim of this trial was to see, a) what affect root pruning and wrenching, started in the 2+0 year, would have on the development of the stock at the end of both the second and third growing season. b) what affect the treatments would have on survival and growth, after out planting, at the end of both the 2+0 and 3+0 seasons. This trial is fully described in Nursery Note No. 100.

Since we planned to outplant the 2+0 age class, it was decided to start the rootpruning procedure after the first of July of the second season, when height growth is virtually finished and bud set has begun. Thus, we felt we would not affect the normal height (13 to 15 cm) of the 2+0 seedling.

We chose four treatments:

1. Operational - Seedlings root pruned at 10 to 15 cm, our normal pruning depth.
2. Shallow - Seedlings root pruned at 5 to 8 cm.
3. 3 week - Seedlings root pruned at 5 to 8 cm and wrenched every 3 weeks, July to October (5 wrenches).
4. 6 week - Seedlings root pruned at 5 to 8 cm and wrenched every 6 weeks, July to September (2 wrenches).

2+0 results - Five replicated samples, from each treatment, were lifted in the fall of 1981 to assess treatment affect on seedling size. Five replicates were also lifted in the spring of 1982 and outplanted.

There were no significant differences in height of the 2+0 stock, nor in diameter except for the "6 week" treatment (Table 6). We are unable to explain why the "6 week" treatment had a smaller diameter than the "3 week", a much more severe treatment. The "3 week" treatment had much better RAI than did the other treatments, 59% better than the "Normal".

Outplanting in 1982, a year of very adequate soil moisture (Figure 1), did not yield any significant differences due to treatment. First year current height growth showed decreasing height growth in response to the

severity of the treatment, with the two "Wrenched" treatments being significantly smaller than the "Shallow" and the "Shallow" smaller than the "Normal". These significant differences disappeared by the end of the second season.

3+0 results - No wrenching treatments were applied in the 3+0 year. Five replicated samples were lifted, from each treatment, in the fall of 1982 to assess treatment affect on seedling size. Five replicates were also lifted in the spring of 1983 and outplanted.

There were morphological differences, for all parameters measured, for the stock lifted in the fall of 1982 (Table 8). The treatments applied in the 2+0 year had affected the 3+0 product size. Generally speaking, except for RAI, the "Wrenched" treatments were smaller than the "Shallow" treatment and the "Shallow" treatment smaller than the "Operational". The effect on RAI was reversed, with the "Operational" treatment having the smallest root area and the "3 week" the best.

Comparing the "Operational" treatment with the "3 week" treatment we find that the TDW was reduced by 26%, HT by 23%, RCD by 14%, T/R by 47%, while the RAI increased by 63%.

It was our feeling, when visually assessing the stock, that the "3 week" seedlings were better looking planting stock than were the "Operational" seedlings.

1983 was one of the drier years on record. Soil moisture relationships were good up to the end of May, then soil moisture declined rapidly until drought conditions were encountered by the end of June. These drought conditions continued through July, August and the first half of September, with only brief respites (Figure 2).

First year survival was affected by the various treatments, with the "Operational" treatment showing the poorest survival and the "3 week" the best (Table 9). This increase, in survival, amounted to 109% when comparing these two treatments.

Once again, first year current height was reduced by the shallow pruning and wrenching treatments. However, as in other years we would expect these differences to disappear by the end of the second or third season.

The important task here is to try and decide why the "3 week" treatment survived at better than double the rate of the "Operational". One might assume that it was because of the much better RAI and T/R ratio of the "3 week". While we are reasonably sure that these were contributing factors, when you compare the treatments for RAI and survival, you find the following:

1. Comparing "Operational" and "Shallow". Increase in RAI = 6.4%. Increase in survival = 60.8%.
2. Comparing "Shallow" and "6 week". Increase in RAI = 13.8%. Increase in survival = 14.7%.
3. Comparing "6 week" and "3 week". Increase in RAI = 34.2%. Increase in survival = 13.7%.

These data show that the largest increase in survival was associated with the smallest increase in RAI, when we compare the "Shallow" treatment with the "Operational" (deep) pruning. Hence shallow pruning would seem to be the most important factor leading to increased survival during a year when soil moisture is a limiting factor.

In summary - pruning and wrenching in the 2+0 year did reduce the size of the 3+0 product, yielding a smaller seedling, with an improved RAI, which survived much better than "Normal" stock, during a season when protracted periods of drought were encountered after planting.

4. 1982 - Our fourth trial was similar to our third, in that pruning was to take place in July of the 2+0 year. It differed in that in the 3+0 year, part of the 2+0 treatments would be subject to a wrenching operation.

2+0
We chose three treatments:

1. Control - No root pruning or root wrenching.
2. Prune - Root pruned at 5 to 8 cm the first week in July.
3. 4 week - Root pruned at 5 to 8 cm the first week in July plus root wrenching every month August to October (3 wrenches).

A four replicate sample was lifted from each treatment in November of 1982 to assess the effect of the various treatments on the size of the stock. Height was the only attribute measured which produced significant differences (Table 10). However since root pruning was not begun until July when height growth was all but completed and bud set had begun, we feel this difference has to be due to something else besides the treatments applied. The "4 week" treatment did not produce the increase in RAI that the "3 week" treatment did in the previous trial. We are not able to explain this discrepancy unless pruning once a month was not often enough to encourage the development of additional fine roots.

3+0

In 1983 the plots were subdivided and a part of each treatment was wrenched on a monthly basis. Thus in the 3+0 season we had six treatments:

1. Control - No treatment applied in either the 2+0 or 3+0 season.
2. Control + W - No treatment applied in 1982 but wrenched monthly in 1983.
3. Prune - Pruned at 5 to 8 cm in 1982, no treatment in 1983.
4. Prune + W - Pruned at 5 to 8 cm in 1982 and wrenched monthly in 1983.
5. 4 week - Pruned at 5 to 8 cm and wrenched monthly in 1982, no treatment in 1983.
6. 4 week + W - Pruned at 5 to 8 cm in 1982 and wrenched monthly in 1983.

A four replicated sample from each treatment was lifted in November of 1983 and forwarded to Prof. R.J. Day at the School of Forestry, Lakehead University, Thunder Bay, Ontario. Prof. Day assigned the seedlings to William M. van Schip, a fourth year student, for measurement, analysis and the preparation of a thesis, in partial fulfillment of the requirements of a BSc. degree in Forestry.

van Schip (1984) found that there were significant differences between HT, RCD, RAI and T/R of the six 3+0 treatments, at the 95% level of confidence (Table 11). Top Dry Weight and Root Dry Weight were not significantly different. NOTE - In Table 11 TDW means Top Dry Weight. In the rest of the tables it stands for Total Dry Weight.

When comparing the "Control" treatment with the "4 week + W" treatment we find the following significant differences, HT was reduced by 25%, RCD by 22%, T/R by 20%, while RAI increased by 55%. While not significant, Top Dry Weight (TDW) decreased by 17% and Root Dry Weight (RDW) increased by 5%.

Thus while the 2+0 results showed no significant differences between treatments, except for height, the 3+0 data showed significant differences between the "Control" and "4 week + W", for all parameters measured, except weight. This illustrates the power of the wrenching treatment in that the "4 week" treatment, which produced the tallest seedling at the end of the second season, when wrenched during the third (4 week + W) produced the shortest seedling.

Summary - Once again root pruning and wrenching only in the 2+0 year did affect the size of the 3+0 product, although significantly so only for height. The effect of the treatment was maximized when root wrenching was carried out in both the 2+0 and 3+0 years.

In our estimation the "4 week + W" treatment (the most severe treatment) produced the best looking seedlings for outplanting. These seedlings had a smaller RCD than untreated stock, but this reduction in diameter appeared to be more than offset by the reduction in height and weight and the increase in root area index.

A five replicated test was planted out in the spring of 1984. To this date (June 15th) we have had a very wet spring and survival of all treatments is approaching 100%.

Discussion

We feel that these four trials prove or at least indicate that the following points are true:

1. Pruning and wrenching in the third year will only marginally effect the size of the 3+0 stock, at least at the densities at which this stock was grown (210 to 270/m^2).
2. For maximum reduction in seedling size and maximum increase in RAI, pruning should be started in the 2+0 year, with wrenching carried out at three to four week intervals during the remainder of the second year and all through the third year.

3. Pruning and wrenching will significantly increase the survival and growth of overwinter frozen stored red pine and most likely condition the stock, so it may be lifted for storage, at least a week earlier than normal.
4. Survival, after outplanting, of shallowly pruned and wrenched red pine, will not be increased during springs with adequate moisture levels but survival will be significantly increased during seasons with prolonged periods of drought.
5. Current height growth, of pruned and wrenched stock, is reduced after outplanting, but this reduction disappears during the second or third season after planting.
6. The success of this technique depends on shallow pruning (5 to 8 cm). The deeper the prune the less the effect.

The tests reported in this summary certainly do not cover the effects of all of the combinations of root pruning and wrenching. Many other combinations could and should be tried, to see how the results of these trials might be modified. In comparing the most severely treated pruned and wrenched root systems with the others, we observed that the increase in RAI was not due to an increase in the number of lateral roots but rather to an increase in the number of fine roots per lateral. This poses the question, could we increase both the number of laterals and the fine roots by beginning root pruning and wrenching in the first season, before all the lateral roots had been initiated?

If pruning and wrenching, starting in mid-July of the second year, does not produce a short enough tree, could we further reduce the height by beginning the wrenching earlier, while the seedling is still actively growing?

Could the reduction in diameter, due to pruning and wrenching, be offset by growing seedlings, to be pruned and wrenched, at a lower density than normal?

Would it be possible to produce a properly pruned and wrenched seedling that would exhibit the properties of a transplanted seedling? Our answer to that question is a resounding YES, with proper timing, pruning

beginning possibly in the first year, with wrenching at intervals of three weeks and with a reduction in seedbed density to around 160 seedlings/m^2.

All our trials so far have been with red pine, our problem species, what will be the result when this technique is tried on other species? Our guess is that it will be as beneficial to them as it has been to red pine. Kemptville is already using shallow pruning and wrenching to control the size of its Jack pine (Pinus banksiana Lamb.) and force it to set bud, and St. Williams has tried root pruning on some hardwoods with, we understand, a real gain in RAI. However we have not heard of any trials where this treated stock was planted out to see how it did when compared to "normal" stock. We feel that all combinations listed here should be tested, not only to see if you get an increase in RAI or if you are able to control height, but also to see if you get a better survival after outplanting, which after all is the name of the game as far as reforestation is concerned.

Suggested Rules for Pruning and Wrenching

1. Pruning must be done shallowly to maximize its beneficial effects (5 to 8 cm). The deeper the pruning is done the less the effect will be, until at 10 to 12 cm there is no effect.

2. The root pruning blade must be very sharp, to prevent it from coming out of the ground. This must likely will mean changing or sharpening the blade every hour or so. At Orono, we also found that after several hand sharpenings, we then had to have the blade precision ground at a machine shop, to keep it operating properly.

3. Constant monitoring of the blade depth, every 20 to 30m, is necessary to make sure the blade is not getting too shallow or too deep. This may be accomplished by a person equipped with a metal pin, graduated in cm, following the pruner in the field and pushing the pin down onto the top of the blade at regular intervals. This will insure that the blade does not get too shallow, at 5 cm the difference between the right depth and disaster is not very much, or too deep where the effect of the operation will be reduced or lost.

4. The soil moisture should be close to field capacity for the pruning operation, so that the roots are held firmly in the soil and the tap root is cut cleanly and completely with as little disturbance to the lateral roots as possible.

5. The root wrenching should be done at a depth below the root pruning cut and the blade should be angled so that the roots are disturbed and the seedbed soil aerated. Tractor speed, for this operation, should be a good fast walk (8 kmh).

6. For red pine, and possible other species, root pruning should begin in the second season, followed by root wrenching, every three weeks, for the remainder of that season and also for the third season.

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van Dorsser, J.C. and D.A. Rook. 1972. Conditioning of radiata pine seedlings by undercutting and wrenching: description of methods, equipment and seedling response. N.Z. Jour For Vol. 17, No. 1. pp. 61-73.

van Schip, W.M. 1984. The effects of root cutting and root wrenching on the morphology of 2+0 and 3+0 Pinus resinosa Ait. seedling stock. Undergraduate thesis, Lakehead University, School of Forestry, Thunder Bay, Ontario. 46 pp.

Table 1. Morphological characteristic 3+0 red pine lifted, Oct. 27/80

Treatment	HT cm	RCD mm	RAI cm^2	TDW 9
3 Week	32.9	5.57	59.7	9.98 b
6 Week	34.1	5.97	65.0	14.02a
Normal	33.0	5.95	55.2	12.38ab
Early	NS	NS	NS	*

Table 2. First year survival % by lifting day

Treatment	Oct. 27	Nov. 3	Nov. 10	Nov. 18	Nov. 28
3 Week	83.2a	80.0a	69.9a	46.6a	93.6a
6 Week	64.8abc	80.0a	60.8a	42.4a	87.2ab
Normal	52.8 bc	71.2a	44.0a	#	64.8 cd
Early	44.0 c	44.0 b	20.0 b	3.2 b	48.0 d
Fresh	74.4ab	74.4a	74.4a	74.4a	74.4 bc
	*	*	**	**	**

Table 3. Average current height pooled lifting dates (except Nov. 18) cm

Treatment	First Yr.	Second Yr.	Third Yr.
3 Week	(5) 5.65 c	(3) 7.50 bc	(1) 15.97
6 Week	(3) 8.46ab	(2) 8.51ab	(2) 14.85
Normal	(2) 8.88a	(1) 9.23a	(4) 14.20
Shallow	(4) 6.51 bc	(5) 6.34 c	(5) 13.24
Fresh	(1) 9.63a	(4) 7.02 bc	(3) 14.76
	**	*	NS

\# - Treatment was inadvertently destroyed.
(1) - Denotes rank.
NS - No significant differences
* - Significant differences at 5% level.
** - Significant differences at 1% level.
Figures followed by the same letter do not vary significantly at the 5% level.

Table 4. 1981 3+0 measurements

Treatment	HT cm	RCD mm	RAI cm^2	TDW g	T/R
3 Week	28.02a	4.87a	62.43	9.57a	3.38a
6 Week	28.10a	4.73a	52.88	9.10a	4.69 bc
1 Wrench	30.08 b	5.05a	55.23	10.16a	4.33ab
Control	32.06 c	5.61 b	63.99	14.49 b	5.76 c
	**	**	NS	***	**

NS - No significant differences.
** - Significant differences at the 1% level.
*** - Significant differences at the 0.1% level.
Figures followed by the same letter do not vary significantly at the 5% level.

Table 5. 3+0 Survival and growth

Treatment	First Year Survival %	First Year Current HT cm	Second Year Current HT cm
3 Week	98.0	7.61a	9.05a
6 Week	98.0	6.78a	6.78 bc
1 Wrench	98.4	10.40 b	6.39 c
Control	97.6	11.60 b	7.75 b
	NS	***	**

NS - No significant differences.
** - Significant differences at the 1% level.
*** - Significant differences at the 0.1% level.
Figures followed by the same letter do not vary significantly at the 5% level.

Table 6. 1981 2+0 Measurements

Treatment	HT cm	RCD mm	RAI cm^2
Operational	12.7	3.41a	25.1 b
Shallow	13.7	3.39a	28.4 b
3 Week	14.3	3.36a	39.8a
6 Week	13.3	3.06 b	29.3 b
	NS	*	**

Table 7. 2+0 Planting survival and growth

Treatment	First Year Survival %	First Year Current HT cm	Second Year Current HT cm
Operational	98.4	14.07a	8.09
Shallow	94.8	12.52 b	6.73
3 Week	96.0	9.13 c	7.35
6 Week	95.2	8.54 c	7.62
	NS	***	NS

NS - No significant differences.
* - Significant differences at 5% level.
** - Significant differences at 1% level.
*** - Significant differences at 0.1% level.
Figures followed by the same letter do not vary significantly at the 5% level.

Table 8. 1982 3+0 Measurements

Treatment	TDW g	HT cm	RCD mm	RAI cm^2	T/R
Operational	13.45a	37.25a	5.67a	42.46 b	7.43a
Shallow	9.32 b	32.86 b	4.81 b	45.18 b	5.89 b
3 Week	9.95 b	28.66 c	4.87 b	69.23a	3.95 c
6 Week	8.24 b	28.46 c	4.60 b	51.39 b	4.29 c
	**	***	***	**	***

Table 9. 3+0 Planting survival and growth

Treatment	First Year Survival %	First Year Current HT cm
Operational	31.4 b	6.56a
Shallow	50.5ab	4.98 b
3 Week	65.7a	5.67 b
6 Week	57.9a	5.12 b
	*	*

* - Significant differences at 5% level.
** - Significant differences at 1% level.
*** - Significant differences at .1% level.
Figures followed by the same letter do not vary significantly at the 5% level.

Table 10. 1982 2+0 Measurements

Treatment	TDW g	HT cm	RCD mm	RAI cm^2	T/R
Control	3.07	11.26a	3.04	29.85	3.64
Prune	3.44	11.36a	3.01	38.63	3.02
4 Week	NS	*	NS	NS	NS

* - Significant differences at the 5% level.
Figures followed by the same letter do not vary significantly at the 5% level.

Table 11. 1983 3+0 Measurements**

Treatment	RCD mm	HT cm	RAI cm^2	TDW[1] g	RDW[2] g	T/R
Control	4.86a	32.44a	22.86a	7.69	1.33	5.9a
Control+W	4.82a	27.84 b	31.26ab	6.83	1.92	3.7 b
Prune	4.53ab	28.30 b	23.05a	7.74	1.50	5.1ab
Prune+W	4.24ab	26.42 b	37.30 b	6.63	1.72	4.1 b
4 Week	4.24ab	26.27 b	25.98ab	5.84	1.07	5.6a
4 Week+W	3.80 b	24.39 b	35.40 b	6.40	1.40	4.7ab

Figures followed by the same letter do not vary significantly at the 5% level.
** - van Schip (1984) data.
[1] TDW = Top Dry Weight.
[2] RDW = Root Dry Weight.

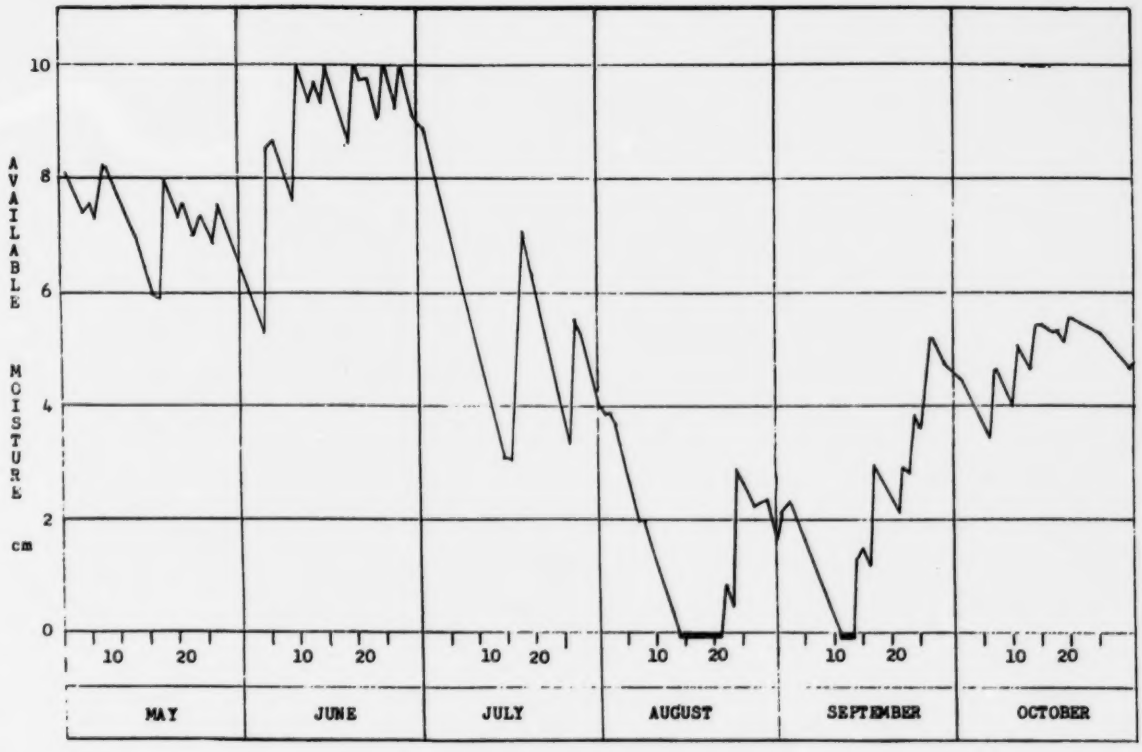

Figure 1. Soil moisture, Orono, 1982.

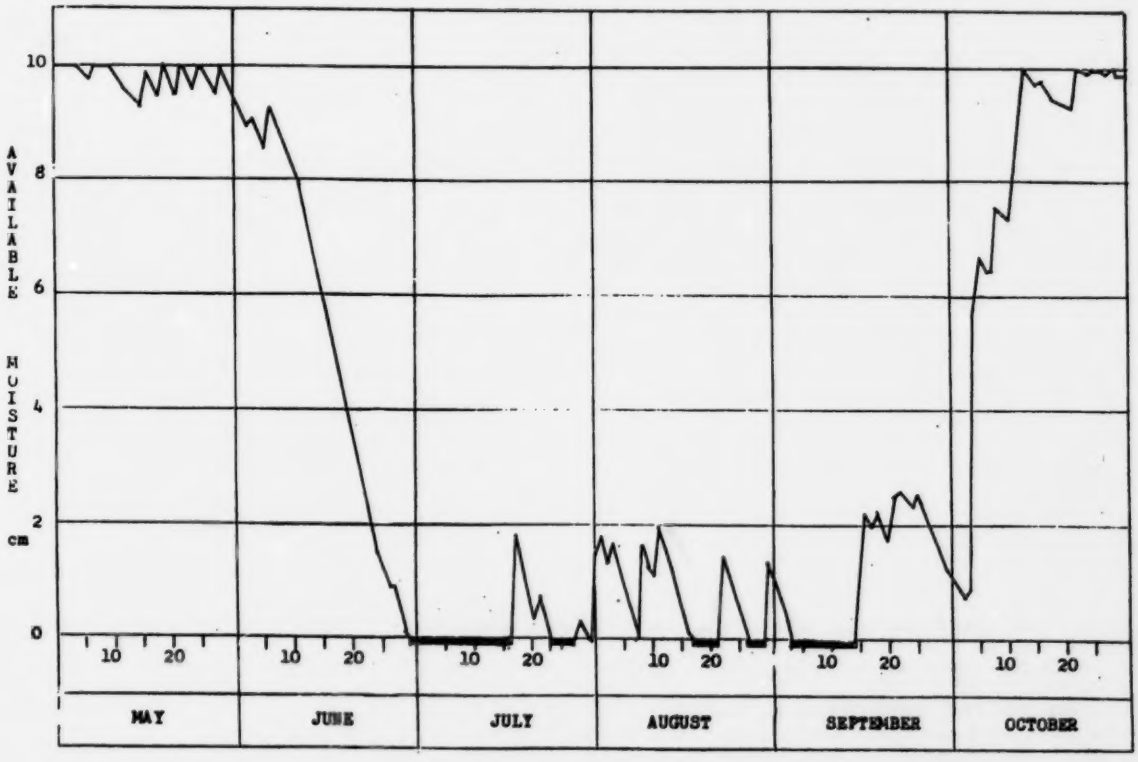

Figure 2. Soil moisture, Orono, 1983.

STOCK PRODUCTION RESEARCH PROGRAM-OVERVIEW

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The objectives of our program are to investigate and develop methods to improve planting stock quality, which should always be high and measurable before it leaves the nursery. The ultimate measure of stock quality is its field performance after outplanting. Therefore, we outplant stock under ideal field conditions at the Midhurst Research Station and under operational field conditions throughout Ontario and monitor the plantings performance for 5 to 7 years (i.e. during plantation establishment phase).

The basic premise in our program is that by understanding physiological attributes such as frost hardiness, dormancy and water relations we can improve the quality of nursery stock. This will mean improved plantation establishment with high survival and rapid growth.

We are trying to develop reliable and quick methods that measure the quality of our planting stock. Some of these methods are in their early stages of development, such as the monitoring of amino acid concentrations in roots and foliage. While other methods are more advanced and are close to becoming operational such as the electrical impedance method for determining safe lifting dates in the fall for overwinter frozen storage. Obviously we are also testing out the degree-hardening-day concept and the square-wave oscilloscope technique for determining safe-lifting dates, and comparing these various methods. This work is presently being done at Midhurst and Swastika nurseries.

At present, we are putting considerable effort in overwinter storage projects but we expect that most of the problems in this area will have been solved towards the end of this decade at which time these projects will be de-emphasized and the program will be realized accordingly to work on other pressing problems.

We are also working on other projects such as stock type testing which is never ending because of the everchanging nursery cultural techniques and the production of new stock types. There are mulching trials to determine the optimum rate of mulching and multiple leadering trials which compare the total performance of multiple leadered seedlings with that of single leadered seedlings. This project is being de-emphasized because of other pressing problems. A project on root soaking of bareroot stock prior to planting has just been initiated in which the extent of soaking is being examined. Preliminary findings indicate that you can soak too long (48 hrs) and that some species such as jack pine may not respond to soaking the same as spruce. There also appears to be a difference in soaking response between overwinter frozen stored stock and fresh spring lifted stock.

The container project, which was formulated in the late 70's and initiated in 1980 has made excellent progress. The extended greenhouse culture technique is a good example of what that project has accomplished. The importance of good bud development and proper hardening on planting stock has been clearly demonstrated.

The work with the pressure bomb to develop pressure-volume curves from which the wilting point is determined for a specific species and stock type through the course of a year has made good progress.

Obviously our group would like to work on more problems which occur in the nursery system and I can assure you that we are eager and willing but we lack the necessary funds.

What do we expect to do in the future? In spite of the present uncertainty of whether or not our group will remain intact on the bareroot scene we plan to establish safe lifting zones at the Dryden, Thunder Bay, Kemptville and St. Williams nurseries in addition to the ones we have for Midhurst, Swastika and Orono nurseries. We plan to continue with more stock type testing in which site comparisons are incorporated. Planting season extension is another important area in which we are going to be involved. On the container scene we are going to work on the 8-hour day treatment to give us greater flexibility with bud development, initiation and removing the crop out of the greenhouse. It will also save a considerable amount of energy and we feel that the additional capital cost required for 8-hour/day treatment will be recovered within one year.

IMPROVING THE QUALITY OF OVERWINTERED CONTAINER STOCK USING EXTENDED GREENHOUSE CULTURE

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Introduction

Prior to 1983, the success with which spruce container stock was overwintered in Ontario was highly variable (Colombo 1982), with damage occurring to as many as 60% of the seedlings in any crop. In some cases, entire crops were lost as a result of winter damage. Perhaps as a result of these inconsistent results the Extended Greenhouse Culture program has developed from a small operational trial involving just a few thousand seedlings in 1982, to where currently almost the entire Province's crop of close to 30 million seedlings are overwintered using this procedure.

The reason crops were susceptible to such severe damage was because the seedlings were given insufficient time to set bud and develop frost hardiness before being moved outside, where they were susceptible to potentially damaging frosts. Using Extended Greenhouse Culture, seedlings remain in the greenhouse until high levels of frost hardiness are achieved.

In addition to reduced levels of winter damage, Extended Greenhouse Culture also results in improved bud development. Buds contain the preformed shoot and needles which will develop the following year, and seedlings with better formed buds will grow more after outplanting than will seedlings with poorly formed buds. Rapid initial height growth is especially important for spruce container seedlings, where their small initial size and the relatively rich sites on which they are planted makes problems with competing vegetation more severe.

At Swastika Forest Station in 1981 and 1982, average bud development ranged from 70 to 120 needle primordia. Using Extended Greenhouse Culture, bud development at Swastika in 1983 averaged nearly 240 needle primordia. Thus, in the space of two years at Swastika, bud development has been increased using Extended Greenhouse Culture by almost 250 percent (Colombo and Odlum 1984). These increases should result in improved plantation establishment using black spruce container stock.

The success in reducing winter damage has been even more important than the improvements in bud developments. Whereas seedlings with small buds can be shipped, trees which suffer winter damage are culled. Winter damage can be avoided using Extended Greenhouse Culture by allowing frost hardiness to develop before seedlings are exposed to freezing temperatures. We have found that when Extended Greenhouse Culture is used correctly, winter damage will be less than 1%.

Monitoring for Extended Greenhouse Culture

The key to using Extended Greenhouse Culture is the monitoring of frost hardiness and bud development as the crop hardens during the fall. Monitoring is necessary to determine when seedlings are ready to be moved outside. If monitoring results are not used to decide when it is safe to move a crop outside, there is a risk of total crop failure. There are now two monitoring centres in the Province, one located in Kirkland Lake and the other in Dryden. A manual for monitoring frost hardiness has been prepared (Colombo *et al*. 1984) to aid nurserymen in the use of Extended Greenhouse Culture.

Frost hardiness of seedlings is determined using a controlled freezing test. Seedlings are exposed to freezing temperatures and, based upon the amount of damage this causes, seedlings are judged to be hardy or not hardy. Bud development and frost hardiness are closely related. It is only following the completion of bud development that seedlings gain a level of frost hardiness great enough to be able to withstand heavy frosts.

The following hardening and monitoring regime for Extended Greenhouse Culture is presently being recommended (Colombo et al. 1984):

1. Fertilization should be stopped and the growing medium leached when the trees are within 3 cm of the desired height. Begin monitoring frost hardiness and bud development on a weekly basis in one greenhouse at each nursery using Extended Greenhouse Culture. In addition, bud samples of seedlings in all greenhouses, at all nurseries, should be dissected weekly until it is determined that 100 percent of the seedlings in each greenhouse have initiated buds. It is important to determine when buds have initiated, because only after that time should nitrogen fertilization be resumed.

2. Once 100% bud initiation has been achieved in all the greenhouses, weekly bud dissections and frost hardiness tests should be started in one greenhouse at each nursery. Greenhouses should be kept at 20 to 30°C (day and night) until it is found that the rate of needle primordia initiation is starting to decrease. This is the sign that seedlings are nearing readiness to be moved outside.

3. At that point, houses should be cooled to between -2 and +5°C whenever possible. Also at that time, frost hardiness tests of seedlings in all greenhouses at all nurseries should begin. Frost hardiness testing should continue until stock in all greenhouses at all nurseries has had two successive tests showing high levels of frost hardiness at -15°C.

Evaluating Improvements in Stock Quality Due to Extended Greenhouse Culture

In 1983 at the Dryden nursery, a trial was performed to determine how much damage would occur if trees were moved outside prior to being fully frost hardened. Trees were moved outside every other week from one greenhouse, beginning July 26. The results of frost hardiness and bud development monitoring are shown in Figure 1. Needle primordia were being initiated until the third week in October and, based on frost hardiness tests, seedlings were not ready to be moved outside until between the first and second weeks of November.

The amount of damage caused at Dryden to seedlings moved outside at different times in the fall are presented in Figure 2. When moved outside July 26 or August 9, the cull rate was 1 to 2%. However, more than 50% of the seedlings moved outside August 23 were damaged. When moved out September 6 or 20, as would have been the practice prior to the introduction of Extended Greenhouse Culture, more than 90% of the trees were damaged. If, however, the trees were left inside until November 1 or later there was no damage at all. This crop was in fact moved outside on the basis if monitoring on November 14, and suffered less than 0.5% damage.

In all cases where Extended Greenhouse Culture was properly used winter damage was less than one percent, resulting in substantial economic savings to the Province. Prior to the introduction of Extended Greenhouse Culture, losses of 20% of overwintered stock were expected in any year. Using this nominal figure, in 1983 when approximately 30 million spruce seedlings were overwintered in Ontario, a total loss of 6 million trees would have been anticipated, with a value of almost $1,000,000. However, when other costs are considered, such as the need to re-prepare sites not planted when stock is unavailable due to winter damage, the economic cost of winter damage can be at least doubled. Improved plantation performance as a result of increased bud development is an additional benefit of Extended Greenhouse Culture, whose value is not easily measured.

While the results using Extended Greenhouse Culture in 1983 confirm the value of this hardening technique, some unrelated problems were encountered. The most serious problem was snow mold damage. Snow mold causes damage to seedlings in the spring as the snowcover is melting. While the damage occurs in the spring, the initial infection takes place the preceding fall.

By following a program of preventative fungicidal spraying in the fall, problems with snow mold can be controlled. It is important that control begin while the seedlings are still in the greenhouse, as grey mold (botrytis) in the greenhouse can develop into snow mold outside. Once the crop is moved outside, fungicide spraying should continue on a regular basis. If seedlings in the greenhouse are large in size, which increases the risk of botrytis, fertilization and watering during Extended Greenhouse Culture should be minimized to help control the potential buildup of botrytis.

The other major problem experienced in 1983 related to moving crops outside prior to sufficient hardiness being achieved. If a commitment is made to use Extended Greenhouse Culture, it is vital that growers be aware that premature removal could result in crop failure. Once committed, a crop should not be moved outside until results from the monitoring centre confirm that it is safe to do so.

Future Developments for Extended Greenhouse Culture

The next development in Extended Greenhouse Culture will be the use of a short day treatment in the greenhouse to speed the rate of frost hardiness development, thus enabling crops to be moved outside earlier in the fall. Under natural daylengths, seedlings begin to set bud during August when the photoperiod is between 13 and 14 hours long (Colombo et al. 1982). If, however, instead of relying on naturally declining daylengths to induce budset, an artificial short day, 8 hour treatment is used, the rate of budset is speeded-up greatly, and, as a result, the seedlings will be ready to be moved outside much earlier. At Swastika in 1983, short day treatment was used on an operational basis in several greenhouses. Seedlings hardened under natural daylengths were ready to be moved outside between October 28 and November 7 (Figure 3). In comparison, seedlings from another greenhouse given short day treatment were ready to be moved outside between September 14 and 21, 8 to 10 weeks earlier (Figure 4). We are now recommending that growers use short day treatment. This will speed the rate of hardening, allowing crops to be moved outside sooner. Besides the obvious savings in heating and maintenance of greenhouses during the fall, short day treatment also allows greenhouses to be unloaded earlier without the risk of snowfall or severe cold. In the Northern Region in 1984, ten private greenhouse operators will be testing the use of short day treatment semi-operationally. Based on their results, short day treatment is expected to become fully operational in all growers in the Northern Region in 1984.

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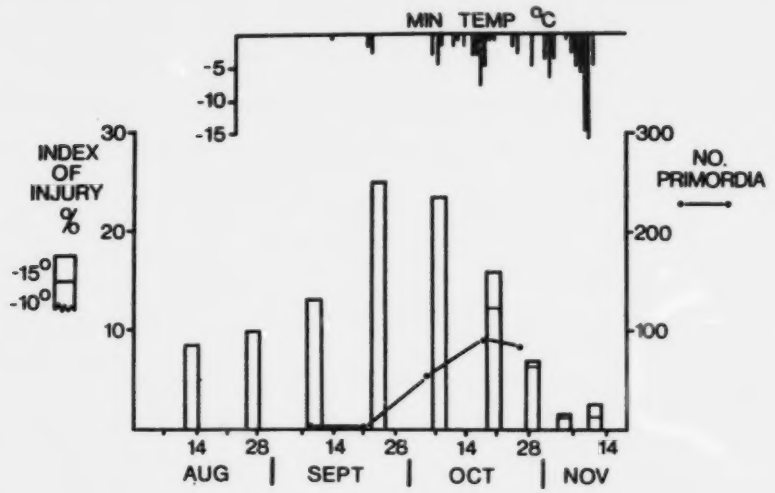

Figure 1. Frost hardiness and bud development in a black spruce container seedling crop at the Dryden Tree Nursery in 1983. Freezing temperatures outside are shown at the top of the graph. Frost hardiness is indicated by bars. Tall bars indicate low levels of frost hardiness while short bars indicate high levels of frost hardiness. Bud development is expressed in numbers of needle primordia contained in the bud.

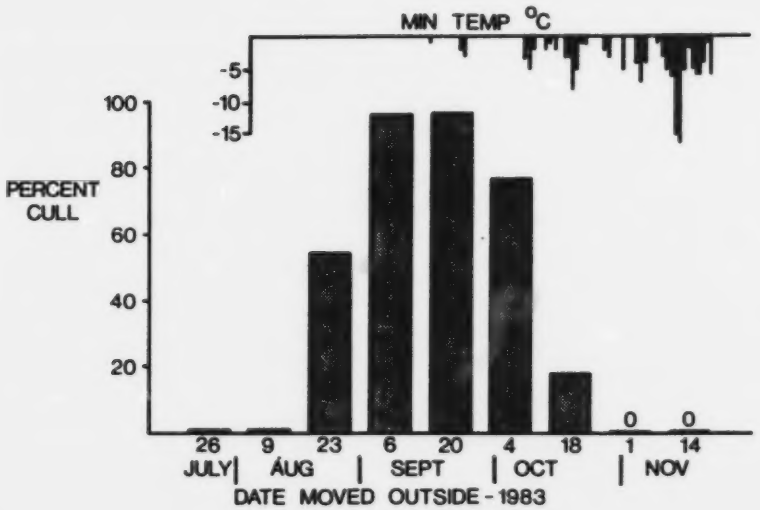

Figure 2. Percent cull seedlings in a black spruce container seedling crop when moved outside at different times of the year. Freezing temperatures outside are shown at the top of the graph.

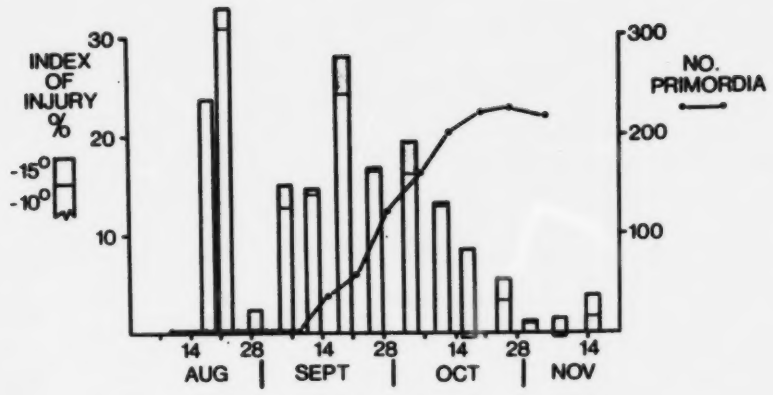

Figure 3. Frost hardiness and bud development in a black spruce container seedling crop at the Swastika Forest Station hardened in 1983 using natural daylengths. See Figure 1 for further explanations.

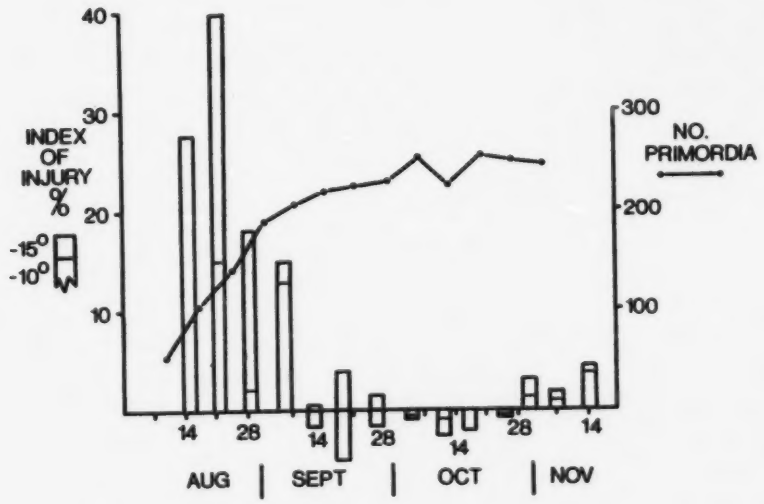

Figure 4. Frost hardiness and bud development in a black spruce container seedling crop at the Swastika Forest Station hardened in 1983 using Short Day (8 hr) treatment. See Figure 1 for further explanations.

READINESS FOR OVERWINTER STORAGE

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The technology associated with overwinter storage of nursery stock has advanced slowly but significantly over the past 40 years. Success has been limited primarily by a lack of application of our understanding of the physiological processes associated with the onset of dormancy and winter hardiness. Most improvements in storage success have been related to the physical storage process: improved storage facilities, better temperature regulation, improved packaging and handling and more efficient transportation practices.

An important criteria for good storage and high planting stock quality is to ensure that the stock is physiologically ready for storage. Readiness for storage is closely related to the onset of dormancy and winter hardiness (but may reflect moisture, temperature and nutritional regimes).

Three techniques are currently available for determining readiness for overwinter storage: Degree Hardening Days (DHD), electrical impedance (EI) and the oscilloscope - square wave method (OSW). The DHD method (Mullin and Parker 1976) is an indirect method based on soil temperatures. The EI and OSW methods are both direct measurements of the electrical properties of stem tissue. Both of these electrical methods are relatively new in their application.

This is an interim report on a project designed to compare the ability of the DHD, EI and OSW methods to determine whether or not coniferous nursery stock is ready for lifting for overwinter storage. The scientific procedures have been downplayed in favour of specific findings or conclusions which have been derived so far.

It is the intent of this project to prepare and present a good, reliable and cost effective method for determining readiness for storage by 1986.

Degree Hardening Days

Degree Hardening Days has been thoroughly tested with regard to fall lifting for overwinter storage. DHD requirements have been prepared for most species (Table 1) although the established requirements are nursery and site specific.

The DHD method is easy to use and quite inexpensive. We use a 7 day recording thermometer with the probe buried 15 cm below the surface of the soil, directly under a bed of seedlings. The chart is removed once a week and DHD values are tabulated and graphed. This procedure must be used for each species and seedbed density, as these factors affect DHD accumulation in any given year (Figure 1).

There is no upper limit to the number of degree hardening days accumulated. Also, because of the nature of accumulation, very large increases can be realized in a relatively short time in late fall. On the other hand, for much of the fall, increases can be very small over a long period of time. One must be aware that DHD is only an indirect measure of dormancy based on the link between cold exposure and the hardening off process.

In some years, trees continue to harden off despite the lack of cold temperatures (Figure 2). This reveals a certain amount of unreliability in this measure which can only be resolved by direct physiological measurements on the tree.

Electrical Methods

The electrical properties of plant stem tissues change with the physiological state of the tree and other physical and environmental factors. All of these factors are frequently confounded when measuring electrical properties of biological organisms. For this reason it is essential that all electrical methods and measures be fully understood with respect to the biological phenomena they are identified with.

In my evaluation of these electrical properties an attempt has been made to identify and separate the major factors influencing both EI and OSW.

Electrical Impedance

Electrical impedance of plant tissue has long been recognized as an identifiable factor which changes with vigor and physiological state (Glerum 1980). Now it appears to have definite potential for determining when trees are ready for lifting for overwinter storage.

The main tool is a 1 kHz impedance bridge with a 2 prong probe consisting of 2 stainless steel pins, spaced 1 cm apart and held firmly in a block of plexiglass. This equipment is relatively cheap and portable but better equipment at lower cost is being investigated.

Impedance varies with stem diameter in a non-linear fashion (Figure 3) but this may be linearized by transforming diameter to $(1/\text{diameter}^2)$ as shown in Figure 4. Therefore, a fairly complex relationship is now reduced to a simple graphical technique that automatically compensates for the diameter relationship (Figure 5).

Impedance also varies with tissue temperature (Figure 6), but the simple linear relationship permits corrected values of impedance to be calculated. Electrical impedance is not a good field measurement because of the difficulty in determining tissue temperature. Therefore, a sample of trees should be measured in the laboratory after being allowed to reach a constant room temperature.

When EI measurements are completed and corrected for differences in room temperature, mean values are plotted (Figure 5). When trees are in the safe lifting zone for 2 consecutive weeks, the trees are ready for overwinter storage.

Oscilloscope - Square Wave

The oscilloscope - square wave method for determining readiness for lifting is a relatively new concept which has been tried with limited success (Holbo et al. 1981). This technique requires a square wave generator and an

oscilloscope which may or may not be contained in the same piece of equipment. The probe which is inserted into the seedling stem consists of 4 stainless steel pins, 1 cm apart, held in a block of plexiglass. The unaltered wave is square in shape and consists of a positive crest and negative trough (Figure 7). This wave is distorted when passed through the tree and it becomes smaller in size, forming a distinctive shape. The shape at the top of the distorted wave is dependent upon the physiological state of the tree (Figure 8) and the degree to which various frequency components of the square wave are filtered out.

The shape of the wave is temperature dependent (Figure 6). Therefore, measurement of the trees in the field is not advisable because the wave trace will be as much a function of temperature as of the physiological state of the tree. Compensation for temperature is not possible due to the complex electrical theory involved and the subjective manner of interpretation.

The actual interpretation of the wave form and its meaning is questionable. Not all species and age classes behave the same and produce the same shape trace while in a similar physiological state. Also, different sections of stem tissue may respond in a somewhat different manner (Figure 9). This illustrates the type of problems encountered with all electrical measurements of biological phenomena but which are more common with the OSW technique than with electrical impedance.

Discussion

These three techniques, EI, OSW and DHD all have their advantages and disadvantages, many of which have already been listed. The remainder of this problem will resolve the issue of which technique is most practical and reliable for use in Ontario nurseries.

To date, our field trials have demonstrated that overwinter storage of red pine, white pine, white spruce, black spruce, and even jack pine may consistently be successful as long as the trees are lifted at the proper time.

At present, the electrical measurements appear to be more promising because they more closely reflect post-storage growth and survival data.

Both of the electrical measurements yield similar information when measured on the root collar, but electrical impedance has a clear advantage in its numerical approach and in its response to rapid changes in physiological state (Figures 10 and 11). Cost will be a major factor and the OSW method is by far the most expensive and time consuming.

This program of testing will provide a recommended methodology by 1986. In the meantime, our work with overwinter storage problems at Ontario nurseries will continue.

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Table 1. Accumulated degree hardening days (DHD) required for lifting 5 species of coniferous trees at selected Ontario nurseries

Species	DHD °C	Nursery	Source	
Black spruce	167	Swastika	Mullin and Hutchison	1978b
White spruce	111	Midhurst	Mullin and Hutchison	1978b
Jack pine	208	Midhurst	Mullin and Hutchison	1978b
White pine	167	Midhurst	Mullin and Hutchison	1978a
Red pine	200	Midhurst	Mullin and Hutchison	1979
White cedar	100	St. Williams	Racey *et al.*	1983
Scotch pine	100	St. Williams	Racey and Hutchison	1983
European larch	200	Midhurst	Mullin and Lucas	1982
Tamarack	140	Midhurst	Mullin and Lucas	1982

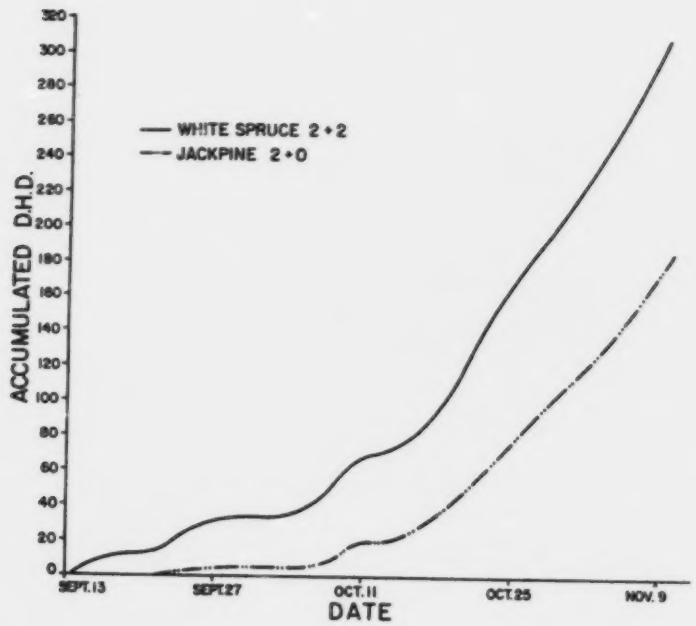

Figure 1. Accumulated degree hardening days at Swastika nusery in the fall of 1983 for soil temperatures under high density, 2+0 jack pine seedlings and low density 2+2 white spruce transplants.

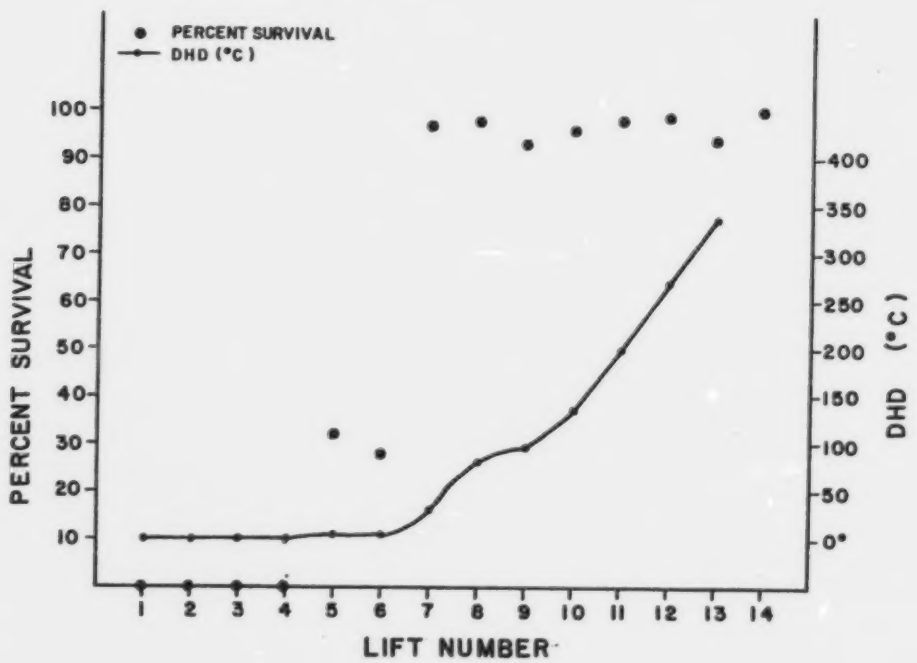

Figure 2. Degree hardening days and percent survival after outplanting for 3+0 red pine lifted from Midhurst nursery in the fall of 1982. Weekly fall lifts began September 7 and finished December 14. The recommended DHD value for red pine is 200°C but trees were ready for lifting long before that.

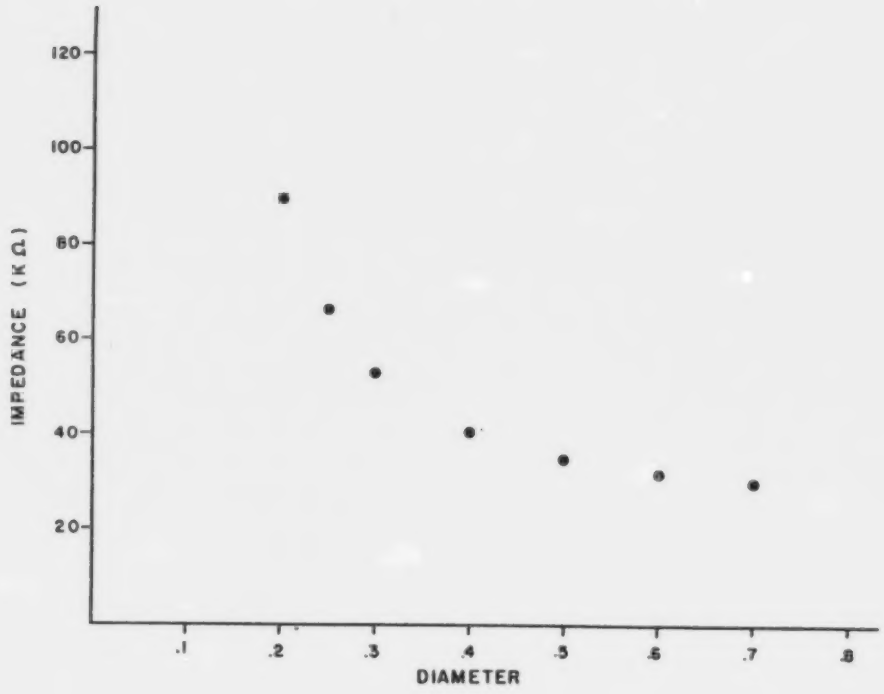

Figure 3. Generalized relationship between electrical impedance and stem diameter.

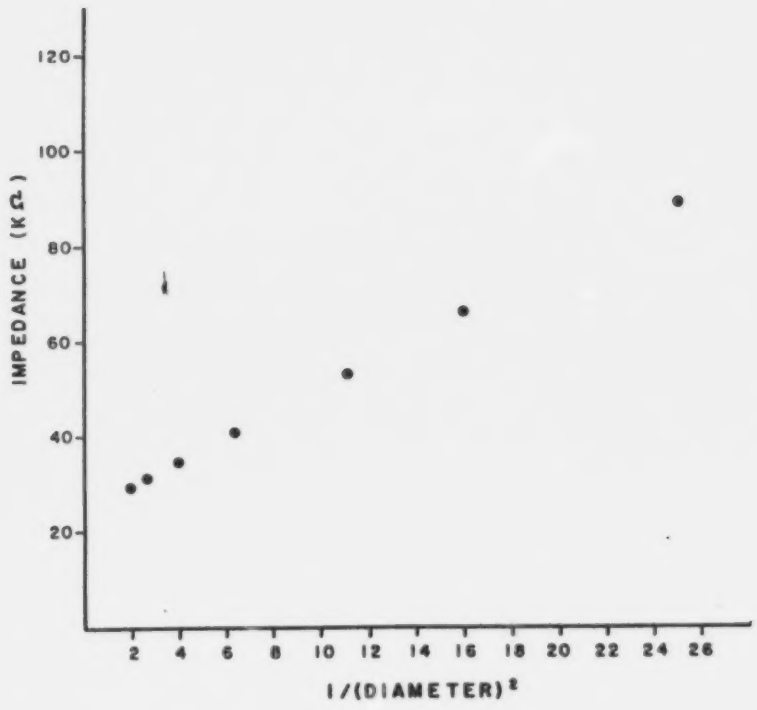

Figure 4. Generalized relationship between electrical impedance and the inverse of diameter squared.

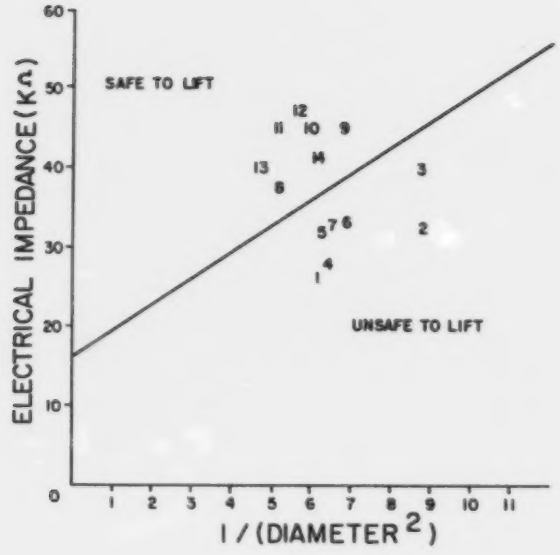

Figure 5. Electrical impedance from weekly lifts is plotted against ($1/diameter^2$) and the established safe-lifting zone. The trees are ready for lifting for overwinter storage when mean impedance readings are in the safe lifting zone for 2 consecutive weeks. Weekly lifts began September 7 and finished December 14.

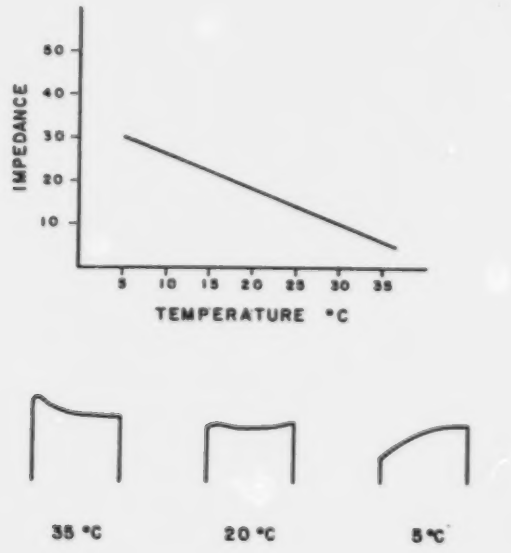

Figure 6. Electrical impedance and the square wave are both affected by temperature. Since the relationship between impedance and temperature is numerical and linear, its values of impedance may be adjusted for temperature. The changes in the square wave may only be determined on a subjective basis and may not be adjusted for temperature.

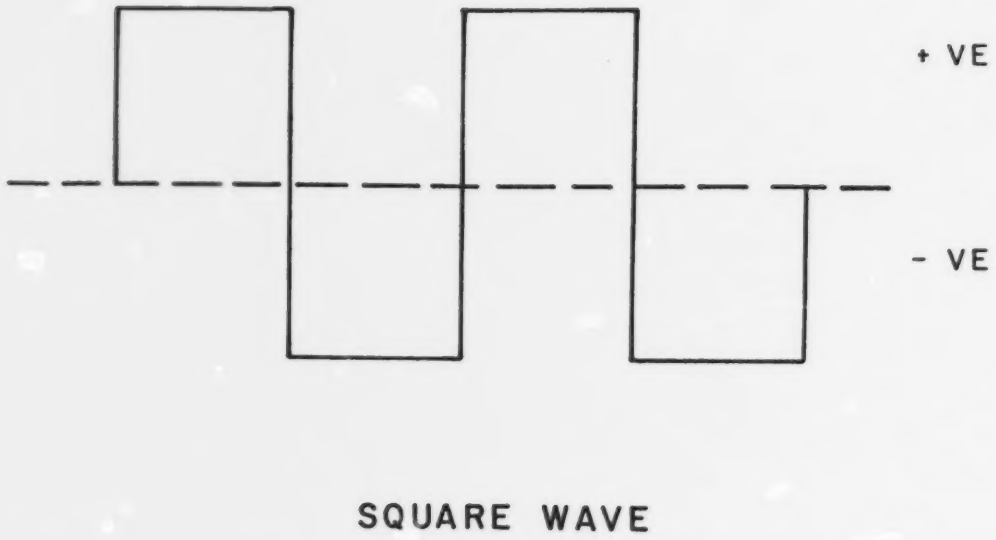

Figure 7. Schematic diagram of square wave produced by a function generator.

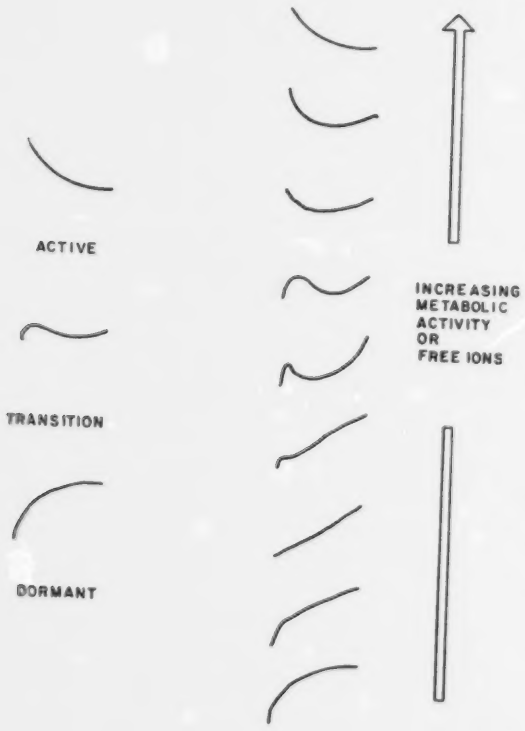

Figure 8. Typical forms of the top of the square wave as they relate to a discrete classification of physiological state (left) and continuum of metabolic activity (right).

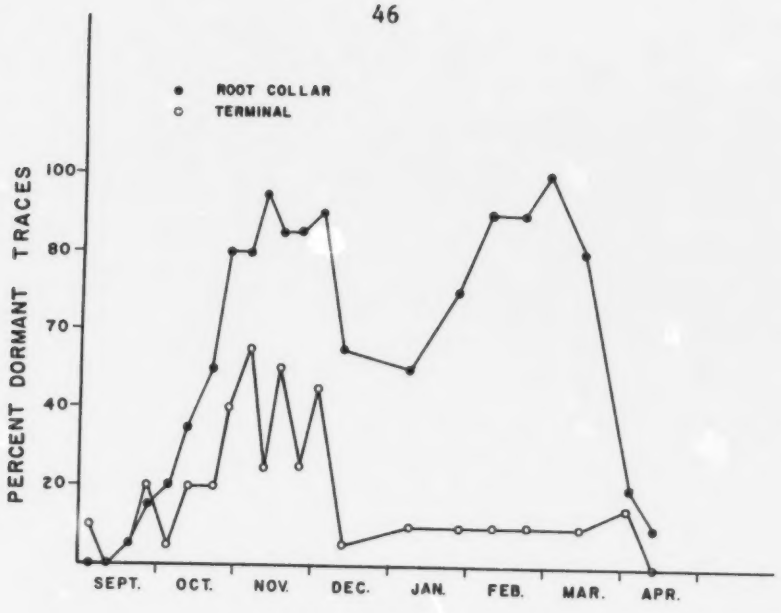

Figure 9. Percent of trees in 20 tree samples of 3+0 red pine from Midhurst nursery with dormant traces on each of 22 lifts during the fall and winter of 1982-83. After reaching room temperatures of 20°C, the root collar measurements continued to indicate dormancy while the terminal shoot measurement did not. The cause of this phenomenon is unknown.

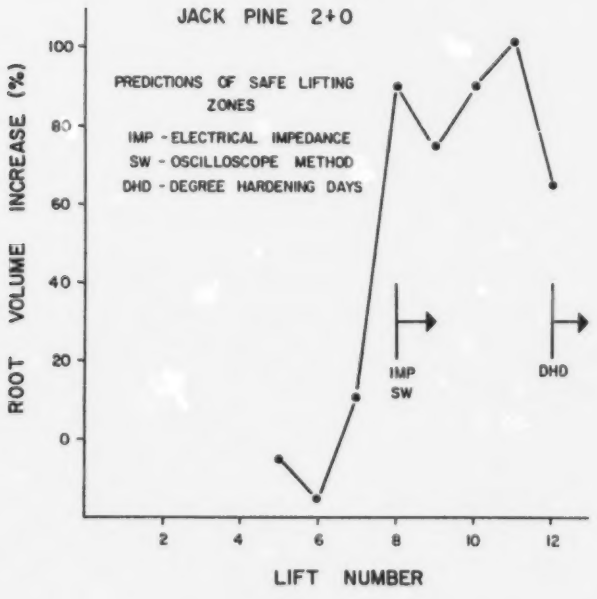

Figure 10. Root regeneration (% of original root volume) of 2+0 jack pine from Swastika nursery in a greenhouse test after storage, plotted against weekly fall lifts beginning August 22, 1983. Impedance and square wave methods both predicted the change in performance while the DHD requirement was not reached until freeze-up.

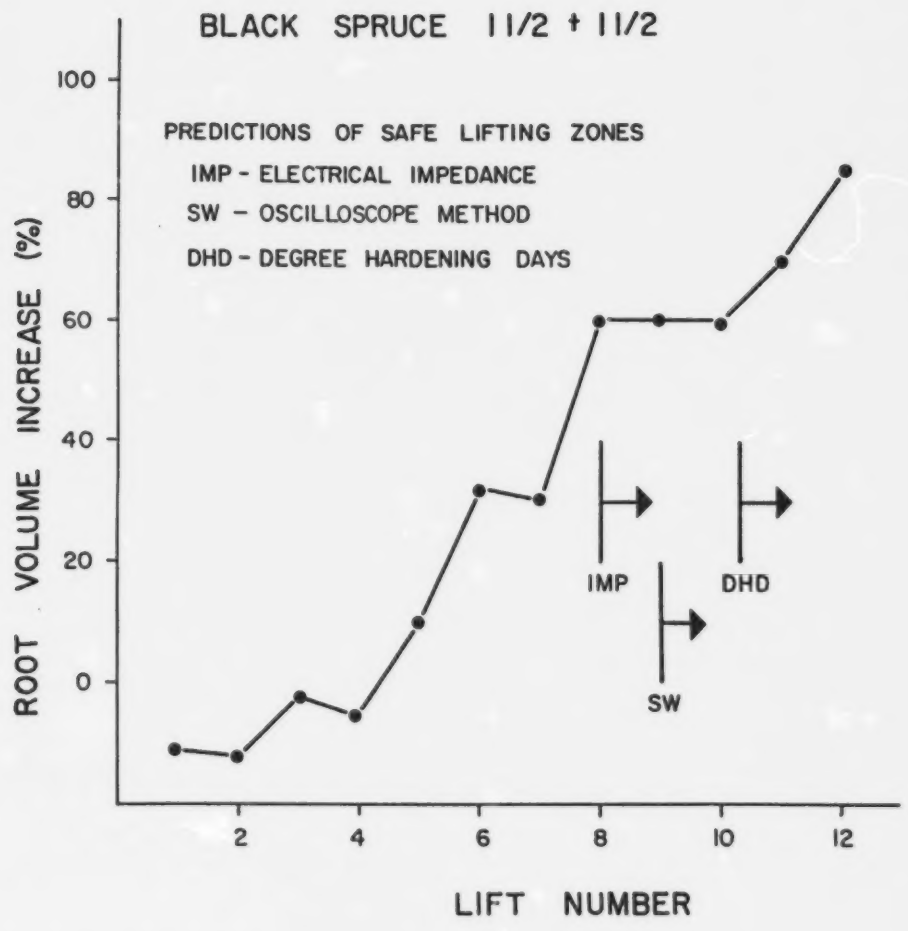

Figure 11. Root regeneration (% of original root volume) of $1^1/2 + 1^1/2$ black spruce from Swastika nursery plotted against weekly fall lifts. Impedance was the first technique to show a positive response while OSW and DHD were later. Intensive testing is required to evaluate effectiveness.

MULTIPLE LEADERING - IS IT A FIELD PROBLEM?

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Multiple leadering (ML) has been a problem at our nurseries for some time, resulting in large amounts of cull at transplant time and again when transplants are lifted for outplanting. Provincial standards for shippable stock relate to size and overall appearance and often dictate the removal of ML trees. Field foresters are unwilling to accept ML trees for outplanting because of insufficient evidence that ML trees revert to single leadered trees.

The decision to cull ML trees from shipping stock was arbitrary and not based on field experience. Some trials in various locations across the province have indicated that ML trees do revert to single leadered dominance but because of location and layouts the results are not sufficiently convincing.

Two questions related to field performance under operational conditions have yet to be answered:

i How well do ML trees survive and grow?

ii Do ML trees revert to single leadered dominance and if so, how long will this transition take?

To answer these questions an outplanting was conducted during the spring of 1983 in Carscallen Township of the Timmins District using various forms of ML white spruce (Picea glauca) 2+2 and 1+2 stock from the Swastika Forest nursery. The first year survival and height increment results by the selected ML forms are discussed in this paper.

Procedure

Prior to lifting 4 broad classes of trees were identified:

Class 1 - Single leader dominance (normal shipping stock).
Class 2.1 - Two leaders with one being at least 2.5 cm taller than the other.
Class 2 - Two equally dominant leaders.
Class 3 - Three or more equally dominant leaders.

For 2+2 white spruce 500 of each class were selected during the operational lift. These trees were packed in the field without being root pruned. An additional 1000 spruce shipping stock were taken as controls and these trees had been root pruned prior to packaging.

The 1+2 spruce had all been previously lifted and was in cool storage. Class 2 plus 2.1 were combined into one class and 150 trees each for class 1, 2 and 3 were selected. No controls were taken since all classes were selected from what was considered to be normal shipping stock.

The total amount of stock used for outplanting was 3000 (2+2) and 450 (1+2) white spruce.

The site to be planted was winter shear bladed. Disturbance to the duff layer was minimal but good planting spots were created. The normal planting layout in a shear bladed corridor is one row down the middle and one row down each side. Five replications of 2+2 spruce were planted with 2 adjacent corridors forming 1 replication. Within each replication all four classes were placed at random after the random placement of a control plot for each corridor. Each replication contained 100 trees of each class and 200 controls replicated five times for a total of 3000 trees. The 1+2 stock was replicated 6 times and planted within one corridor. Each replication contained three classes of 25 trees each randomly placed within the corridor with each replication backing on the previous one for a total of 450 trees.

The conditions at time of planting were anything but ideal. The soil was saturated and the trees were planted through 10 cm of freshly fallen snow.

In the fall of 1983 the planting was assessed for survival, annual increment and total height. In addition, each tree planted was reclassified into the four broad classes previously described for its initial nursery condition.

For assessing new field growth the classification system underwent some minor revisions. The first year height increment was assessed as follows:

Class 1 - Annual increment on one terminal leader in 100% above the increment of any secondary terminals.

Class 2.1 - Two terminals with one being 51% to 99% above the increment of the other.

Class 2 - Two terminals with one being less than 51% above the increment of the other.

Class 3 - Three or more terminals with none being less than 51% above the increment of any of the others.

This revised classification system allowed for a quick visual assessment technique. It also provided a visual transition to single leader dominance.

Results and Discussion

An analysis of variance on the survival data, after arc sine transformation, showed no replication effect but did show a treatment effect at the 95% level. Survival differences were then tested with the Duncan's new multiple range test. Mean height increments were compared by calculating confidence intervals at the 95% level.

Not all trees were properly classified prior to planting, the survivals presented in Tables 1 and 2 are based only on trees properly classified after planting and reflect the survival of the specifically selected nursery class.

For the 2+2 spruce, class 3 and 2 trees did not differ significantly from each other but were both significantly better than class 2.1, 1 and shipping stock (Table 1). The class 3 trees were also significantly better than the class 1 trees for the 1+2 stock (Table 2).

The shipping stock, used as a control in the 2+2 plant, did not show these survival differences when compared by nursery class (Table 3). Root pruning prior to packaging plus normal delays during lifting operations may partially account for the survivals being lower and more uniform than the stock which I packaged.

The first year height increment on the 2+2 stock showed similar results as those shown for survival (Figure 1). The class 3 trees were significantly better, for first year height increment, than class 2.1, 1 and shipping stock. The class 2 trees were significantly better than class 1 and shipping stock while class 2.1, 1 and shipping stock were not significantly different. The 1+2 stock showed no significant differences between classes although the class 3 trees had less increment (Figure 2). Root pruning may have caused an inbalance of root to top on the class 3 trees resulting in poorer growth.

From the data presented it is obvious that multiple stemmed trees survive and grow well in their first season after outplanting.

Changes in growth form from the original nursery class to first year class are shown in Tables 4 (2+2) and 5 (2+1). Both age classes are showing conversions in class towards single leaders (class 1) by the end of the first year based on my classification criteria. The largest percentages, however, still remain within the original class with one exception 2.1 (Table 4). In this class, a larger percentage had moved to class 1 (50%).

It is too early to form any major conclusions from this data but early indications are that multiple stemmed trees (class 3) survive and grow as well as or better than single leadered trees (class 1). Changes in leader dominance appear to be occurring by the end of the first year but should be monitored in future years before definitive conclusions can be reached.

Table 1. Percent survival of 2+2 stock by nursery class

Nursery class	Original number planted	Original number Properly classified	Percent survival [a]
3	485	468	98.1a
2	485	383	95.8a
2.1	482	320	92.5b
1	495	482	91.5b
Shipping stock	968	968	89.5b
Combined classes	2915	2621	92.7

[a] Percent survivals not followed by the same letter differ significantly at the 95% level.

Table 2. Percent survival of 1+2 stock by nursery class

Nursery class	Original number planted	Original number Properly classified	Percent survival [a]
3	150	123	96.8a
2 and 2.1	149	134	94.0ab
1	150	125	91.2b
Combined classes	449	382	94.0

[a] Percent survivals not followed by the same letter differ significantly at the 95% level.

Table 3. Percent survival of 2+2 shipping stock subdivided by nursery class

Nursery class	Number planted	Percent survival [a]
3	169	88.8a
2	172	90.7a
2.1	97	88.7a
1	530	89.4a
Combined classes	968	89.5

[a] Percent survivals not followed by the same letter differ significantly at the 95% level.

Table 4. Percent change by class from nursery to first year after outplanting for 2+2 shite spruce

Nursery class	Sample size	First year class %			
		3	2	2.1	1
3	459	55	19	15	11
2	367	3	64	25	8
2.1	296	2	14	34	50
1	441	3	2	0	95
Shipping stock	886	10	16	10	64

Table 5. Percent change by class from nursery to first year after Outplanting for 1+2 white spruce

Nursery class	Sample size	First year class %			
		3	2	2.1	1
3	119	43	20	19	18
2 and 2.1	126	4	31	43	22
1	114	3	1	0	96

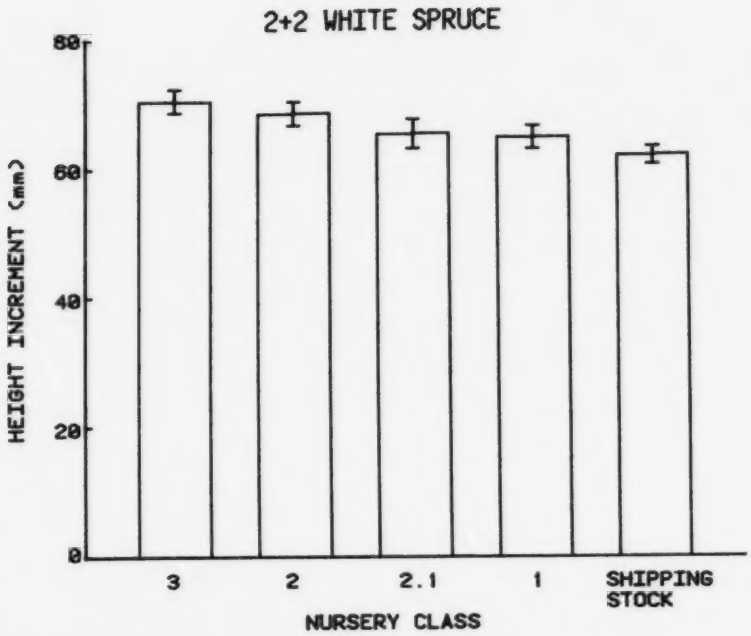

Figure 1. First year increment by nursery class on outplanted 2+2 white spruce. Confidence intervals calculated at the 95% level.

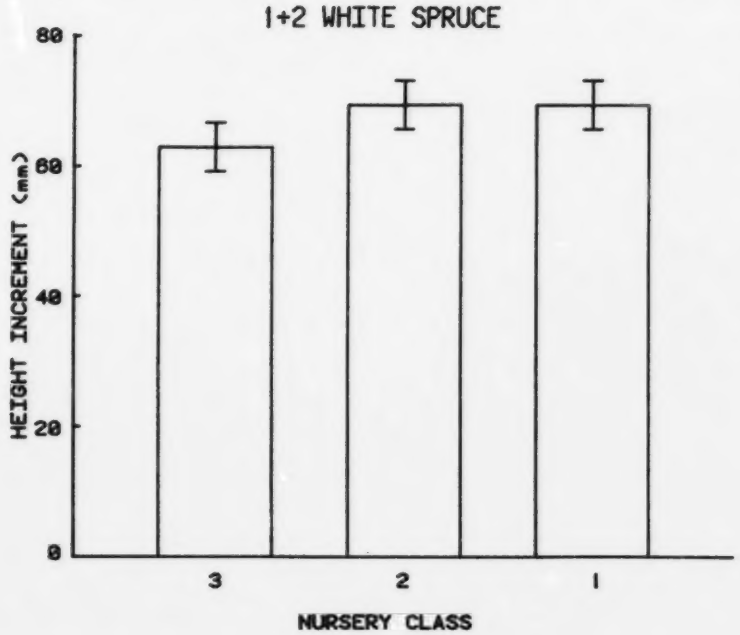

Figure 2. First year increment by nursery class on outplanted 1+2 white spruce. Confidence intervals calculated at the 95% level.

PANEL DISCUSSION

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Chris Glerum: ROOT PRUNING AT TIME OF LIFTING

When we were asked to set up this panel we were encouraged to be controversial to stimulate discussion, and this we intend to do.

I would like to discuss briefly the practice of root pruning at time of lifting which occurs at all nurseries. Root systems are pruned anywhere from 12 to 6 inches (30 to 15 cm). When you prune to get a 12 inch (30 cm) root system you remove about 15% of the root system, and you remove over 50% when you prune to 6 inches (15 cm). Obviously the exact percentages are stock type dependent. This pruned root material contains water, nutrients and food substances which you in effect remove from the tree. Besides that, as soon as the contact between soil and roots has been broken, the roots start to dry out from the tips inwards. By pruning you move these tips upwards closer to the base of the tree. We should remember that the roots dry out faster than the tops.

It is for these reasons that we do not recommend root pruning at time of lifting, except for long runner type roots and if root pruning is deemed necessary, we recommend that it is done at time of planting but definitely not earlier.

Bob Hutchison: ROOT SOAKING AT TIME OF PLANTING

The operational practice of root soaking prior to outplanting does not fall into the main theme of a nurserymen's meeting, but I do feel that the procedure warrants discussion. As nursery people you may also have comments and questions on the physiological monitoring of relative moisture content (RMC) and plant moisture stress (PMS) prior to the trees leaving the

nursery and the value of the monitoring information at the nursery and field level, particularly when this information is not used to modify the planting practices.

Recent concerns prompt me to ask if MNR field staff, along with company and contract people, have been instructed to implement an operational procedure that possibly might deteriorate the physiological condition of some planting stock instead of improving it. I believe we should take a closer look at root soaking to provide a more precise set of guidelines for each of the three major species in Northern Ontario.

A recent survey of the six Northern Region districts identified a number of concerns expressed by Ministry staff. These people are directly involved with the operational aspects of the root soaking process and these concerns centered around: 1) the effects of fluctuating and freezing water temperatures, 2) length of soaking time, 3) capacity of roots to absorb water, 4) loss of mycorrhiza through water soaking, 5) how often should water be changed? 6) is there a difference between the use of swamp, stream and lake water? 7) how low can water oxygen levels go before we suffocate trees? 8) should there be a climatization period for frozen white spruce stock prior to soaking? 9) values of PMS readings, 10) how low can RMS values go and the trees still recover? 11) availability of other monitoring techniques besides the time consuming RMC procedure, 12) lack of confidence in current monitoring techniques as demonstrated by the minimum 4 hr soaking time for all stock regardless of monitored PMS and RMC values.

To me this represents a fairly involved list of concerns, therefore, we should have answers for it on a per specie basis.

Recent tests by Midhurst staff showed that the pH levels decrease in root soaking water for both black spruce and jack pine. This indicated a substantial loss to the tree roots of parent nursery soil material.

Up to 80% reduction in dissolved oxygen levels were noted in 1°-2°C cold water treatments over a 1 to 48 hr period for black spruce and jack pine. Ambient water temperatures of 5-6°C showed even greater reduction in oxygen levels.

Root soaking over a 48 hr period produced variable PMS levels for late spring lifted jack pine. PMS levels on the other hand using fall lifted jack pine continued to increase with the length of soaking time. This inability to absorb water could be the reason for the mortality of early spring lifted stock experienced during the 1984 planting season in the Northern Region. This early spring lifted jack pine appears to have the inability to absorb moisture when soaked, even though acceptable PMS and RMC levels were experienced at the time of lifting.

These observations are preliminary, but indicate the need for additional research into the practice of root soaking.

INTERPRETING THE SIGNIFICANCE OF PLANT MOISTURE STRESS BY MEANS OF THE PRESSURE-VOLUME TECHNIQUE

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Introduction

The availability of water is a key factor affecting the growth and survival of tree seedlings in the nursery and following outplanting. The importance of seedling water status has resulted in the development of methods for determining the plant moisture stress of tree seedlings. The principle method used in forestry is the pressure chamber.

The Pressure Chamber Technique

The first pressure chambers were constructed in 1914 by H.H. Dixon (1914). These pressure chambers were somewhat dangerous to use, however, as they were constructed of glass and would, on occasion, explode. Dixon abandoned this line of research before serious injuries were inflicted (Ritchie and Hinkley 1975). It was not until the 1960's that the pressure chamber technique was revived by an innovative team of researchers at the Scripps Institution of Oceanography of the University of California headed by P.F. Scholander (Scholander *et al*. 1965). Scholander's pressure chambers were constructed of metal, so avoiding the hazards experienced by Dixon 50 years earlier.

The first pressure chamber in Ontario was constructed and tested at Maple in 1966 by G. Pierpoint and C. Glerum at the Research Branch of the then Department of Lands and Forests. The pressure chamber was popularized as a tool for nursery use in Ontario by R.J. Day of Lakehead University in the 1970's (Day 1980).

Current Uses of the Pressure Chamber

The pressure chamber is primarily used to monitor the plant moisture stress of bareroot nursery stock at time of lifting in MNR tree nurseries. In recent years some MNR field staff have begun to monitor plant moisture stress of nursery stock at the planting site as well. With the advent of Forest Management Agreements, stock quality is increasingly being recognized as a key factor affecting plantation establishment. As a result, some companies now use the pressure chamber for monitoring plant moisture stress of nursery stock at planting. Plan moisture stress of container stock is not normally monitored in the nursery, but is occasionally measured at the planting site.

Problems in the Interpretation of Plant Moisture Stress Readings

At present, there is an important shortcoming in the use of the pressure chamber for measuring plant moisture stress. While the readings obtained using a pressure chamber are an indication of the degree of water stress in a seedling, that in itself does not indicate what level of water stress the seedling can withstand before growth loss or damage occurs.

There is presently no specific information available which can be used to determine when plant moisture stress readings exceed acceptable levels. Thus, stock which has been exposed to moderately high (10 to 15 bars) and high (greater than 20 bars) levels of plant moisture stress cannot be judged as to quality, unless the critical level of plant moisture stress which reduces the quality of that stock is known.

The tolerance of tree seedlings to high levels of plant moisture stress changes seasonally (Mullin 1967, Hermann 1967). For example, seedlings which have been in frozen overwinter storage will have a low level of activity when taken from storage in the spring and should be able to withstand relatively high levels of plant moisture stress without suffering damage. In comparison, four to five weeks after planting these same seedlings will be actively growing with succulent new roots and shoots. These trees would be susceptible to damage at much lower plant moisture stress levels than when inactive.

The problem of interpreting critical levels of plant moisture stress is thus complicated by the changing stress resistance of stock in different

stages of development. For operational use of the pressure chamber as a tool for assessing nursery stock quality, it is necessary to be able to determine critical plant moisture stress levels for seedlings in all stages of development. One means by which the level of stress resistance of nursery stock can be estimated is by determining the wilting point by means of the Pressure-Volume technique (Scholander et al. 1965, Tyree and Hammel 1972).

Determining Critical Plant Moisture Stress Levels

The Pressure-Volume technique has been modified at the Ontario Tree Improvement and Forest Biomass Institute for operational nursery and field use to identify the wilting point of nursery stock. When plant moisture stress reaches the wilting point, growth will be retarded or will stop. Thus, the wilting point can serve as a first-estimate of critical plant moisture stress levels for nursery stock.

The Pressure-Volume technique is an extension of the pressure chamber method for measuring plant moisture stress. In the Pressure-Volume technique, excised seedling shoots are allowed to slowly air-dry so that the relationship between water loss and increasing plant moisture stress can be determined. The procedures for constructing a Pressure-Volume curve are outlined in Appendices A and B. In summary, up to 30 shoots, fully hydrated by water soaking overnight, are allowed to air-dry, and each shoot is sampled once during drying to determine weight loss (equivalent to water loss) and plant moisture stress. For each shoot a single point is entered on a graph of reciprocal plant moisture stress (1/PMS). A complete set of such observations yields a Pressure-Volume curve (Figure 1).

Initially, as water is lost from fully hydrated seedlings, 1/PMS falls rapidly. At the wilting point, however, the relationship between 1/PMS and water loss becomes a straight line. By determining graphically the point at which the Pressure-Volume line becomes linear, the wilting point is found.

Seasonal Variation in the Wilting Point

Using the wilting point as an estimate of critical plant moisture stress, it is possible to evaluate the changing resistance of nursery stock to plant moisture stress over the course of the growing season.

To evaluate the extent of seasonal changes in the wilting point, a trial was performed at Maple using black spruce container seedlings during their second growing season. Three trays of FH408 paperpot seedlings grown at the Swastika Nursery in 1983 were overwintered at Maple. On March 9, 1984, while the roots remained frozen, the trays were moved inside a greenhouse (maximum and minimum temperatures of 16 to 28°C, daylength 16h). Samples were collected twice-weekly for analysis of the wilting point during bud swelling, flushing and shoot elongation. After 9 weeks in the greenhouse, budset was initiated by an 8 h short day treatment using opaque plastic shades.

Changes in the wilting point over time are shown in Figure 2. When first brought into the greenhouse the trees were fully dormant and the wilting point was 28 bars, its greatest measured value. The wilting point decreased steadily as buds became swollen (wilting point of 24 to 22 bars) and finally broke (wilting point of 21 to 16 bars). During shoot elongation the wilting point was at its lowest level and did not vary greatly during that time (wilting point of 14 to 15 bars). When short day treatment was used to induce bud initiation, the wilting point rose gradually from about 15 bars to 23 bars on the final sampling date, when bud development was complete.

Conclusions and Future Research Directions

The Pressure-Volume technique can be used to determine the stress resistance of nursery stock as indicated by the wilting point. This can allow nurserymen and foresters to determine the susceptibility of their nursery stock to damage by moisture loss.

Measurement of the wilting point by the Pressure-Volume technique should be done at the time nursery stock is shipped. Such information should be included as part of the shipping record. Nursery and field staff could then determine whether plant moisture stress levels of stock were within acceptable levels.

Based on preliminary research trials, we expect that nursery stock is able to tolerate levels of plant moisture stress which exceed the wilting point by between 5 to 10 bars. Thus, stock with a wilting point of 20 bars may be capable of withstanding a moisture stress of 25 to 30 bars without significantly reducing planting stock quality.

Our current investigations are designed to evaluate the effects of different levels of plant moisture stress on subsequent seedling growth and survival. Stock of a known wilting point is allowed to dry to the wilting point and beyond. Seedlings are then potted, placed in a greenhouse and observed over a 4 to 8 week period for visual signs of damage. In this way, lethal stress limits as measured by plant moisture stress can be related to the wilting point determined with the Pressure-Volume technique.

Another area of investigation is designed to determine cultural methods of increasing the stress resistance of nursery stock. Practices which increase the wilting point of nursery stock have the potential to increase growth and survival after outplanting, thereby reducing losses due to drought, one of the chief causes of plantation failure. Procedures being investigated include the use of undercutting and wrenching, periodic moisture stressing by drying nursery beds or container trays, and potassium salt (ion) "loading" of container stock.

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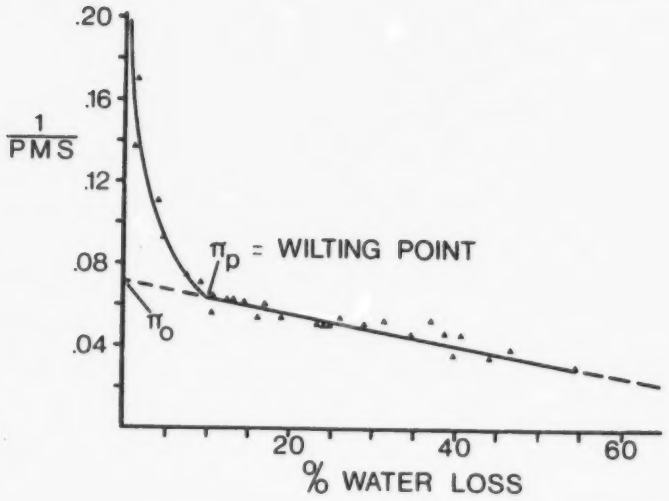

Figure 1. A typical Pressure-Volume curve showing a wilting point of 15.6 bars (1/0.064).

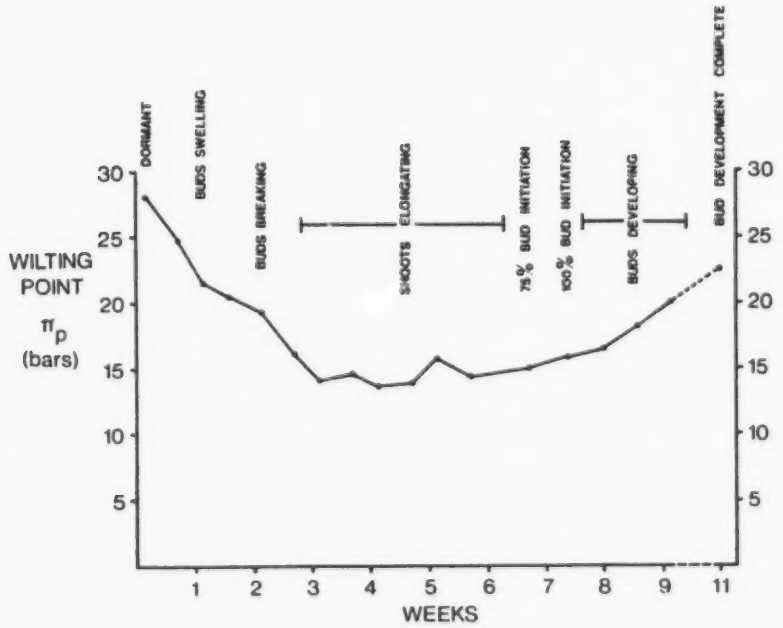

Figure 2. The relationship between stage of shoot growth and the wilting point of black spruce container seedlings.

APPENDIX A. Operational Procedure for Constructing Pressure-Volume Curves

(1) Collect 30 shoots, excised at the root collar, and place their basal ends in 1-2 cm water. Seal the container and shoots in a dark plastic bag to maintain a high humidity around the shoots.

(2) After 12-24 hours of soaking remove a shoot from the water. Number the shoot and cut it to a standard length (usually between 5 and 15 cm long). Prepare the shoot for insertion into the pressure chamber. Measure the fully saturated weight.

(3) Allow the first shoot to air-dry for between 1 and 5 minutes.

(4) Measure plant moisture stress.

(5) Immediately after depressurizing the pressure chamber weigh the shoot a second time.

(6) Oven-dry and weigh the shoot (90°C for 24 h).

(7) Repeat the procedure (Steps 2-6) for each additional shoot, gradually increasing the length of drying time by 10 to 15 minutes for each successive shoot.

(8) When all the shoots have been sampled, complete the table in Appendix B.

(9) Plot weight loss versus reciprocal PMS (1/PMS), as shown in Figure 1.

(10) Determine by graphical methods the plant moisture stress at the wilting point (the wilting point is the inflection point as shown in Figure 1).

APPENDIX B. Data sheet for preparing Pressure-Volume (P-V) curves

Tree no.	Fully saturated weight (a)	Weight after drying (b)	Weight loss (c) = a-b	Oven dry weight (d)	Percent weight loss (e) = $\frac{c}{a-d}$ x 100	$\frac{1}{PMS}$ (f)	PMS (g)
1							
2							
3							
4							
5							
6							
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CULLING PRACTICES

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Many factors contribute to the total amount of stock culled by the time lifting operations are completed. This culled stock, if systematically sampled, can reveal valuable information to nursery growers when evaluating their total operation. This paper outlines a sampling technique used at three northern nurseries (Dryden, Thunder Bay and Swastika) for black spruce (Picea mariana) and white spruce (Picea glauca) during the spring lifting operations in 1983-84. A breakdown of the various culling factors observed and a cost summary for the production of this cull stock are also presented.

Procedures

The five transplant compartments sampled were randomly selected from those compartments being lifted during my stay at each nursery. After the lifting operation was completed in the compartment to be sampled, 3 equal size sample plots were randomly located. The size of the sample plot was determined on a per/metre basis with 3 plots representing roughly 5% of the total metres being lifted. All trees within the sample plots were collected and subdivided into six cull groups. The six groups and their descriptions were:

1. Physical damage - Damage caused during the lifting operation such as torn roots and broken tops.
2. Bent roots - Roots oriented in one direction (hockey stick) or stems deformed.
3. Shippable stock - Stock of shippable size often buried during the lifting operation or were just within shippable size standards.

4. Multiple stems - Trees with more than 3 competing terminal leaders.
5. Dead - Trees which died shortly after transplanting or in the year just prior to lifting.
6. Poor size - Any tree which did not meet height and diameter standards or had a poor root to top balance. Included in this group were trees with bent roots and multiple stems which did not meet minimum height standards.

Since the compartments and cull sample plots were defined in lineal metres, trees shipped plus trees culled would equal trees planted per metre. This now allowed for the calculation of percent cull and the percent cull for each of the six cull groups.

Results and Discussion

The three nurseries combined had a total production for black and white spruce, of 17 million shippable trees. The percent cull removed from production, based on my sample, represented 33% or just over 8 million trees. Had all trees been shippable, production would have been 25 million trees and total production costs to produce shippable stock would have been greatly reduced.

Percent cull between sample plots varied but percent cull distribution by the six cull groups between plots was similar. Table 1 shows the percent contribution of each cull factor to total cull for the three nurseries combined and their production costs based on $75/1000. Poor sized stock was the major contributor in 1984 and cost roughly $17/1000 to produce.

It should be kept in mind that percent cull will change from year to year and with good nursery management should be kept to a minimum. To reduce cull the major causes must first be identified. This can be achieved by sampling the compartments after lifting. Once the major contributors to cull are identified, the cultural practices should be reviewed and those which could account for the cull should be adjusted so that similar problems are corrected in future crops. Monitoring the amount and type of cull stock that occurs each year will aid in the identification of problem areas and show the effects caused by changes in cultural treatments.

I observed while comparing 2 compartments at the Dryden nursery in 1983, that date of transplanting had an influence on the percent cull. Trees transplanted on May 28 had 4 percent less dead and 18 percent less in the poor size class than those transplanted on June 11. Further checking of compartment records could have revealed a more definite cause and once corrected, similar problems would be reduced in future crops.

Application of nitrogen late in the growing season, prior to bud set, can prevent frost hardiness development. Trees which are not frost hardy are prone to frost damage of the apical meristem and will result in multiple leadered development and reduced size. Differences in multiple stem development do occur between compartments. By comparing cultural treatments within low incidence and high incidence compartments it may be possible to isolate a possible cause.

The procedure outlined in this paper can identify problem areas. When compartments, which have received different cultural treatments, are compared it would reveal what effect these treatments have had. Adjusting cultural treatments to correct potential problems will, with time, reduce cull, improve stock quality and eventually lead to bed run shipment of transplant stock.

Table 1. Cull sample showing percent distribution by cull factor and the nursery cost for production based on 5 compartments sampled in 1984 at Dryden, Swastika and Thunder Bay

Cull factor	% Distribution	Cost @ $75/1000
Physical damage	3	$ 1.00
Bent roots	7	2.00
Shippable stock	8	2.00
Multiple stems	11	3.00
Dead	12	3.00
Poor size	59	17.00
	100	$ 28.00

ROOT VOLUME OR ROOT AREA INDEX?

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The suggested theme for this meeting is stock quality which can be divided into physiological and morphological quality. Most of the stock quality measures currently used are morphological.

Morphological quality pertains to size and form and most nurseries have an active program to monitor morphological quality from year to year. These measures are made primarily to identify changes or trends in the type of stock being produced. This information is useful in the evaluation of fertilization and watering procedures and general cultural practices.

I suggest that root volume be adopted as a stock characterization measure at Ontario nurseries. This measure is fast, repeatable and highly correlated with outplanting performance. Furthermore, the equipment is relatively inexpensive and very versatile. Root area index and root volume are similar in many ways:

1. The most vital factor concerning roots of bareroot nursery stock is their ability to establish new roots thereby facilitating the absorption of water and nutrients. This ability cannot be detected by either root area index or root volume.

2. The number, location and age of the fine fibrous roots, which provide the most efficient absorbing surface, are important morphological criteria. The relative proportion of coarse and fine roots is also important to the tree. Silhouette area or volume, measure size only not absorbing surface.

3. A device which could measure and evaluate number and length of fine and coarse roots would provide a measure superior to both root volume and root area index. As yet, no such device is available to the nurseries for laboratory use at a reasonable price.

Root area index and root volume are highly correlated (Racey et al. 1984) over the normal range of RAI and root volume for the major Ontario species. However, RAI fails to detect significant proportions of white root tips due to their translucent nature (Racey in preparation). This causes a bias in RAI which is avoided by the root volume measurement. This is particularly true when a large number of white root tips are present as in the determination of new root growth (Figure 1) where the root volume measure is able to detect large increases of root size, represented by long white root tips. In this case, it provides a valuable supplement to actual measurements of number and length of new roots.

The rhizometer is a piece of equipment for one purpose only. It measures root area only, while the balance required for root volume estimation, is versatile and may be used for numerous other functions around the nursery such as soil samples and fresh and dry weights of seedlings.

Since the measurement of root volume is cheaper and faster, provides as much information on roots in half the time, and uses more versatile equipment than root area index, it can greatly increase the efficiency of laboratory procedures for morphological characterization of nursery stock.

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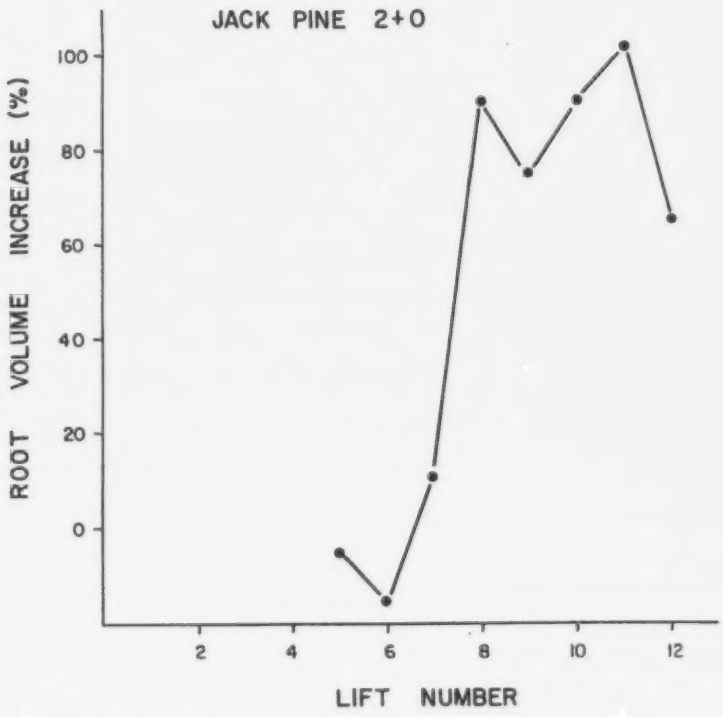

Figure 1. Percent root volume increase in 2+0 jack pine lifted at weekly intervals in the fall for overwinter storage. Root growth tests were done in a greenhouse after a minimum of 2 month of storage. Lifting began mid-August and finished in mid-November at Swastika nursery.

SOIL FERTILITY PRESCRIPTIONS FOR BAREROOT NURSERY STOCK PRODUCTION

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The program for monitoring soil fertility at forest nurseries operated by the Ministry of Natural Resources normally involves collecting soil samples and sending these to Glendon Hall Research Laboratory (University of Toronto) for chemical analysis. Soil sampling is generally confined to the plow layer or Ap horizon of the beds since most of the roots of the seedling crop are distributed in this layer (Armson 1972). Using a core sampler or auger, at least 30 representative soil samples are collected along a random zigzag pattern within a compartment. These samples are thoroughly mixed to form a bulk sample of the entire field, and a sub sample of the composite is sent for laboratory analysis. The analytical results provide the data base for formulating fertilizer recommendations for the next growing season.

The aim of the soil testing program is to assist nursery soil management by 1) diagnosing possible nutrient deficiencies, 2) warning of excessive fertilization of seedling crops, and 3) prescribing fertilizer rates to maintain levels of nutrient availability in nursery beds.

Optimum Levels

Prescriptions for fertilizer requirements are based on known relationships between the nutrients status of the specific soil and the upper level of fertilization needed for the crop. Optimum (critical, guideline, target, or recommended) soil nutrient values are usually derived from a program of field calibration trials which determine the concentration of soil nutrients coincident with maximum growth or yield of the crop. Experience

from Ontario forest nurseries has shown that the following levels of nutrients are considered adequate for optimum production of most bareroot, coniferous nursery stock (Armson and Sadreika 1979).

Soil nutrient	Concentration per 100 g soil
Available phosphorous (P)	30.0 mg
Exchangeable potassium (K)	0.3 meq
Exchangeable calcium (Ca)	1.5 meq
Exchangeable magnesium (Mg)	0.5 meq

General guidelines for controlling acidity in nursery soils consider pH 5.0-6.0 desirable for growing most conifers, and a higher range of pH 6.0-7.0 necessary for most hardwood stock. A target goal of 3.0% organic carbon (or 5.0% organic matter) in soils is assumed sufficient for seedling growth at most nurseries.

The plow layer as a reference unit

Since nursery seedlings derive their nutrients mainly from the rooting zone of the soil, rates of fertilizer application are calculated on the basis of the amount of nutrients needed to raise the soil plow layer to desired fertility levels. Hence, the "hectare-furrow-slice" (or "acre-furrow-slice") is used as a reference unit for these calculations.

The weight of a hectare-furrow-slice depends on its depth as well as its bulk density. Generally plow depths in nurseries range from 15 to 20 cm. Combining the greater depth with a common bulk density of 1.0 g/cm^3 (and remembering that density = mass/volume), the mass of the plow layer can be calculated as:

$$\text{Weight of plow layer} = 1.0\ g/cm^3 \times \frac{20\ cm \times (100\ cm/m)^2 \times 10{,}000\ m^2\ (ha)}{1{,}000\ g/kg}$$

$$= 2{,}000{,}000\ kg/ha = 2\ million\ kg/ha$$

The same result can be obtained by assuming a shallower depth but a higher bulk density, such as 15 cm and 1.33 g/cm^3. A hectare-furrow-slice is, therefore, often assumed to weigh 2 million kg as a reasonable estimate. Since pounds per acre (the comparable unit in the Imperial

system) is approximately the same as kilograms per hectare, the two units are often considered equal, and an acre-furrow-slice is taken as weighing 2 million lb. If a more accurate conversion is needed, the factor 1.0 lb/ac = 1.12 kg/ha may be used. It must be remembered that the 2 million value is an approximation which may often be off by 10-20 percent in either system.

Converting soil analyses to field use

In spite of being an approximation, the 2 million kg/ha or lb/ac value is widely used for converting laboratory data to field use. Soil analysis results are usually reported in relative terms as parts per million (ppm), milligrams per 100 grams (mg/100g), or milliequivalents per 100 grams (meq/100g). Multiplication by 2 converts ppm to pp2m (parts per 2 million) for use on either a kg/ha or lb/ac basis. Similarly, multiplying 20 times an equivalent weight converts meq/100 g to pp2m or kg/ha. Hence, soil analyses expressed in concentration values can be easily converted to absolute quantities in the plow layer utilizing the appropriate conversion factors, as shown in Table 1. It can be seen that the various amounts of macronutrients required for producing a satisfactory conifer crop in a hectare-furrow-slice of a typical tree nursery are 600, 234, 600 and 122 kg/ha of P, K, Ca and Mg, respectively.

Table 1. Levels of soil nutrients in the plow layer considered optimum for producing bareroot conifer stock in Ontario nurseries

Soil Nutrient	Levels in the soil				
	meq/100 g	mg/100 g	ppm[b/]	pp2m	kg/ha
Avail. P	-	30.0	300	600	600
Ex K^{+}	0.3	11.7[a/]	117	234	234
Ex Ca^{++}	1.5	30.0[a/]	300	600	600
Ex Mg^{++}	0.5	6.1[a/]	61	122	122

a/ to convert meq to mg multiply by equivalent wt (equivalent wt = atomic wt/valance.

b/ to convert mg/100 g to ppm, multiply by 10.

Fertilizer prescriptions

Fertilizer prescriptions relate current nutrient status of the soil (determined by soil tests) against optimum target levels. The amount of elemental fertilizer required for maximum growth is the difference (in kg/ha) between the optimum level and that of the soil sample. For example, a sample recording 20 mg/100 g of available P would represent 400 kg P/ha in the plow layer, which would require 600-400 or 200 kg/ha of fertilizer P to raise its concentration to the optimum. A compartment with 0.1 meq/100 g (or 78 kg/ha) exchangeable K in the plow layer would need 234-78 or 156 kg K/ha to bring soil K status to optimum conditions.

These calculations assume that the prescribed rate of fertilizer application is completely effective (i.e. 100% efficient) in raising soil nutrients to the target level. Appropriate factors compensating for excessive leaching and/or substantial fixation of added nutrients on specific soils, or under particular management systems, would need to be incorporated in the calculation to adjust for such losses. For instance, prescriptions for P fertilizer at Thunder Bay may be much higher than those at Orono because of differences in the P-fixation capacities of the soils. Under laboratory incubation the degree of phosphate-fixation was much higher for a Thunder Bay soil compared to an Orono soil (Figure 1). Fertilization trials recently carried out at these nurseries have confirmed these interpretations.

It is important to note that the fertilizer quantities prescribed for raising soil nutrient status to optimum are expressed in elemental form (such as P or K), not in the oxide form (such as P_2O_5 or K_2O) usually reported on the fertilizer bag. Fertilizer analysis can be converted from oxide to elemental form using a multiplier of 0.436 for P, and 0.83 for K. These conversions will simplify calculations for the actual amount of fertilizer material needed in the field, since analysis vary with branch, source, or type of fertilizer used at the nursery.

Although there are several chemical means for evaluating both the amount and form of N in the soil, the tests have limited success in predicting plant available N over the growing season. Hence, recommendations for N fertilizer applications are not usually based on soil analysis.

Instead, rates and frequency of top dressings for N are guided by growth development and nutrient demand of the seedlings, and are scheduled on a cumulative degree day basis (Armson and Sadreika 1979).

Empirically derived adjustment factors

Calculations for ameliorating soil pH and organic matter to desired levels in nursery beds make use of empirically derived adjustment factors. Mullin's (1964) work with Orono soils has shown that between the range of pH 5.0-7.5, powdered sulfur incorporated at 112 kg/ha will reduce soil pH by 0.1 units. This factor will vary of course with soils of different buffering capacity.

Early experience with peat additions has lead to the following adjustment factor: 24 m^3 of fibrous peat will normally increase soil organic C by 0.1% (Armson and Sadreika 1979). Obviously this value changes with different types of organic material and/or rates of subsequent decomposition. More recent calibrations of known additions of peat to seedbeds have shown that this adjustment factor is too low for most of the peat sources available at nurseries. To improve accuracy, prescriptions should be based on bulk density determinations and organic carbon analysis of the organic materials.

Improving soil fertility

Table 2 compares soil test values from a natural forest stand with those from an adjacent nursery compartment (H 21) at Swastika nursery. The two soil pits were located on level terrain less than 50 m apart, thus it is reasonable to assume similar profile development and nutrient status before nursery establishment. Subsequent clearing, tillage and cultivation have mixed the forest floor, the eluviated (Ae) horizon and part of the Bf horizon into a well defined, dark coloured plow layer (Ap).

As can be seen, the A-horizon test values from the natural stand are decidedly lower than those of the nursery bed, illustrating the inherent low fertility of sandy soils. The contrast in nutrient status exemplifies the effectiveness of nursery management in improving fertility for intensive crop production. Prescribed amendments of peat and fertilizers have raised target levels in the Ap horizon close to optimum, except for K

concentrations which were still moderately low. The pH was increased by incorporation of organic matter that was relatively high in Ca content. Effects of leaching and residual acidity commonly associated with heavy fertilization were reflected in the analysis of underlying B and C horizons: these exhibited increased exchangeable K and reduced pH. Available P status in the nursery subsoil was somewhat lower than that of the natural stand, presumably because of greater acidity.

Table 2. Chemical analyses of mineral soil horizons from pits located in a natural forest stand (jack pine) and in an adjacent transplant compartment (H 21) at the Swastika nursery, June 1984.

Soil Horizon	pH	Organic C	Total N	Available P	Exchangeable K	Exchangeable Ca	Exchangeable Mg	CEC[b/]
Stand:		%	%	mg[a/]	meq[a/]			
Ae	4.0	0.5	0.03	0.7	0.02	0.11	0.04	2.8
Bf	5.8	0.8	0.04	1.5	0.03	0.53	0.07	3.7
BC	6.3	0.2	0.01	10.8	0.01	0.30	0.06	1.5
C	6.3	0.1	0.01	4.6	0.01	0.21	0.04	1.0
Nursery:								
Ap	4.9	2.9	0.13	27.4	0.17	6.03	0.54	10.9
Bf	5.0	1.1	0.05	2.2	0.09	0.51	0.02	4.8
BC	5.4	0.3	0.02	9.0	0.06	0.21	0.02	1.4
C	5.5	0.1	0.01	1.7	0.13	0.14	0.03	1.1

a/ per 100 g soil
b/ Cation Exchange Capacity

Research support

The reliability of a soil testing service is highly dependent on a support program of nursery research to calibrate analysis techniques, develop interpretations, and verify prescriptions. This work is undertaken cooperatively by staff of the Ministry of Natural Resources and Faculty of Forestry, involving demonstration trials, field experiments, greenhouse studies and laboratory analysis. Bunting (1984) recently validated fertilizer prescriptions for 2+0 white spruce seedlings at the Orono nursery. He demonstrated that N additions short of the recommended rate

depressed height growth significantly, while excess dosages failed to improve height development. At each N level, supplementation with P and K above prescribed rates failed to increase growth significantly. Hence, recommended rates of N, P and K applications induced the best growth.

Trials in other nurseries testing conventional fertilizer application at higher than regular dosages have in most cases demonstrated little or no improvement in seedling growth. Although at Midhurst, Parton and Timmer (1983) found that extra N, P and K applied as a nutrient solution combined with a 2-time foliar spray of micronutrients substantially improved survival and dry matter production of 1+0 black spruce (Figure 3). Surprisingly, follow-up trials at Midhurst and Swastika nurseries in subsequent growing seasons failed to detect similar responses to micronutrient deficiency, although extra macronutrients applied in solution-form increased growth significantly. The same treatments were generally ineffective on white spruce and white pine seedlings.

The pH requirements for hybrid poplar production were determined by liming and acidification experiments (Timmer 1985). Optimum soil reaction for height growth of poplar cuttings ranged between pH 6.0-7.0 (Figure 4), which agreed well with guideline values prescribed for hardwood production. The use of good quality, fibrous peat as material for ameliorating organic C levels in the soil has become costly for nurseries in southern Ontario. Chemical analysis of various local and cheaper sources of organic material were conducted to assess their suitability as alternative sources to peat (Timmer 1981). Other studies on growing media analysis (Timmer and Parton 1984), foliar diagnosis (Timmer and Morrow 1984), and irrigation monitoring (Bunting and Timmer 1981) form and integral part of the research program. The findings are useful and relevant to current management practices dealing with nursery soils.

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Timmer, V.R. and W.J. Parton. 1984. Optimum nutrient levels in a container growing medium determined by saturated aqueous extract. Commun. Soil Sci. Plant Anal. 15: 607-618.

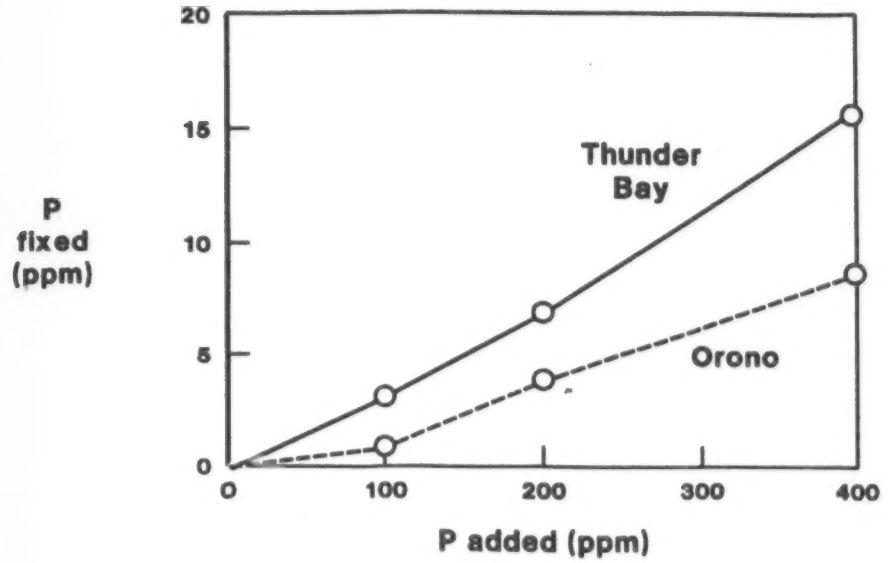

Figure 1. Comparative phosphate fixation capacities of Thunder Bay and Orono nursery soils. Amount of P fixed is the difference between P added and that extracted after 72 h incubation at 30°C.

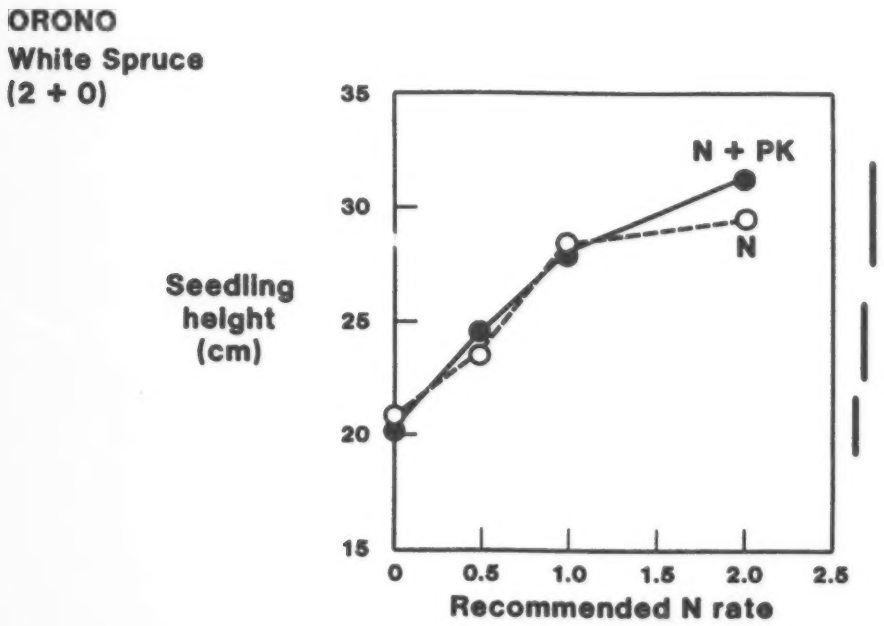

Figure 2. Mean height growth of 2+0 white spruce at Orono subject to various N regimes (recommended rate: 5 top dressings at 84 kg N/ha each). PK treatment consisted of 2 top dressings each at 93 kg P/ha and 56 kg K/ha that supplemented prescribed rates (adapted from Bunting 1984). Any two means falling outside the range delineated by the same verticle bar are significantly different, P=0.05.

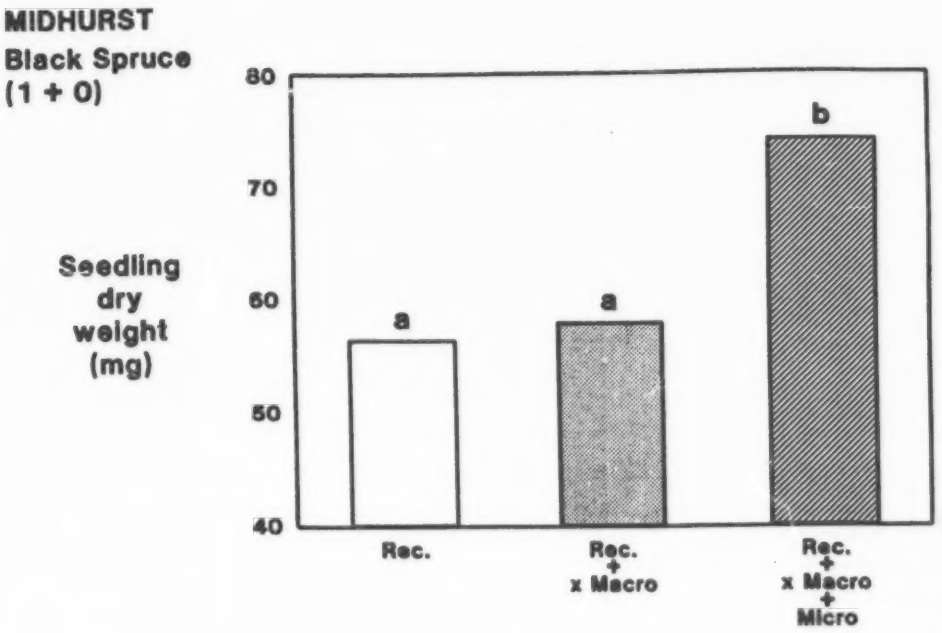

Figure 3. Dry weight of 1+0 black spruce at Midhurst treated with recommended NPK fertilizer application (rec), supplemented with extra macronutrients in solution (rec + xmacro), and foliar sprays of a mix of micronutrients (rec + xmacro + micro) (drawn from Parton and Timmer 1983).

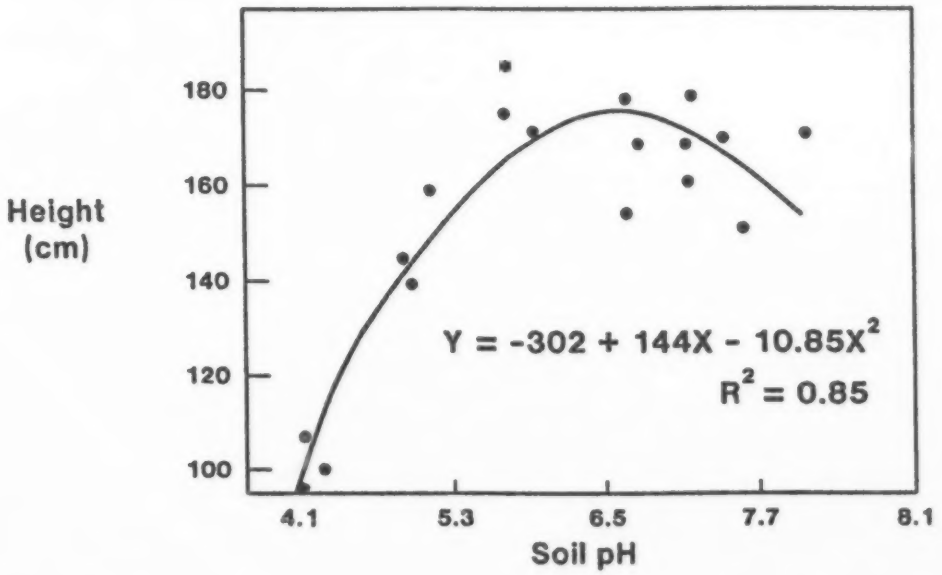

Figure 4. Height of 20 week-old hybrid poplar cuttings (clone DTAC-32) growing at varying pH of a Kemptville nursery soil altered by liming and sulfur treatments (from Timmer 1985).

FOREST NURSERY SOIL MANAGEMENT IN THE ATLANTIC REGION: A REVIEW OF CURRENT PRACTICES

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Forest nursery soil management in the Atlantic Region follows, in principle, the guidelines established by Armson and Sadreika (1979). However, soil and climate vary considerably and the requirements for planting stock differ from province to province. This variability has imposed different types of constraints to which nursery superintendents presumably have responded in the most appropriate manner. It would not be unusual, therefore, if current practices in a certain nursery deviated substantially from the standard method if such existed.

This report is a generalized account of basic methods applied in forest nursery soil management in the Atlantic Region today. It is based largely on the information from a questionnaire sent to the principal nurseries of the region and it aims to facilitate the exchange of experience, for progress is rarely achieved without communication.

Type of Stock and Level of Production

The region currently produces slightly more than 80 million trees per year. About 30% of the production is bareroot stock and the remainder container stock (Table 1). New Brunswick is leading with approximately 70% of the total regional production. In this province, most of the stock (about 73%) is produced in containers. Nova Scotia, with the second largest production, raised a similar proportion of the plants in containers. A similar ratio is shown for Prince Edward Island, but in Newfoundland, bareroot production exceeds container stock production.

Most of the stock, about 64%, is produced in provincial nurseries (Table 2). Industries raise approximately 31% of the total stock. Most of the industrial production (about 53%) originates from one company. Small

amounts of container stock are raised in small private greenhouses on a contract basis with a Nova Scotia pulp and paper company, and another small contribution to the total production is made by a Scott Paper International, Inc., nursery within a medium security institution of Correctional Services of Canada in Nova Scotia.

There appears to be a trend towards higher transplant than seedling stock production (Table 3). This is due to the strong emphasis on transplant stock by the Province of Nova Scotia and one industrial nursery, and the policy not to raise bareroot seedling stock for field planting in Newfoundland.

Black spruce is the species produced in largest quantities in the Atlantic Region (Table 4). In the provincial facilities of New Brunswick black spruce and jack pine are produced in approximately equal numbers. However, jack pine plays an insignificant role in Nova Scotia nurseries and is not propagated at all in Newfoundland, but it ranks second in the overall rating because of the large output by New Brunswick nurseries. This species is being raised predominantly in containers. Black spruce and jack pine are followed by white spruce and red pine. Balsam fir is raised mainly as transplant stock in provincial facilities for Christmas tree culture. Red spruce, although an important reforestation species in Nova Scotia, ranks only sixth on a regional basis. Of lesser significance are eastern larch, white pine and Norway spruce. Eastern larch is being given increased attention in the industrial nurseries of New Brunswick.

Soil Management

The perhumid climate of the Atlantic Region contributes to accelerated acidification of soils derived from acidic geological materials and subjected to intensive cropping. This applies to bareroot planting stock production as well as to agricultural cropping. Returns to the questionnaire (Table 5) indicated pH values from 5 to 6 desirable for nursery production in the Atlantic Region. To maintain the pH in the desired range the soils in all but one of the responding nurseries are limed periodically or occasionally. The nursery reporting no use of lime is of recent origin with a limited number of crops raised to date.

Organic matter maintenance

The individual nurseries have set targets for soil organic matter ranging from 4.5 to 15%. Materials used for treatment include peat, sawdust and manure. Three of the six nurseries raise green-manure crops occasionally or on a regular basis. Types of green-manure crops used are buckwheat, rye and oats. It is interesting to note that the nurseries with the highest targets for soil organic matter are those with peat deposits adjacent to or in close vicinity of the production areas.

Organic soil amendments are normally made at the time of seedbed or transplant bed preparation. To achieve the high levels of organic matter as desired in two of the nurseries, peat is being applied at rates of 375 m^3/ha (approximately 200 cu. yd./acre) or larger. It is also customary to use peat as a mulch on seedbeds. The main purpose is to protect 1-year-old seedlings from frost heaving. Application of a 2-cm thick layer of peat corresponds roughly 200 m^3/ha and should raise the organic matter content of the soil by approximately 0.7% if all of it were eventually incorporated into the top soil.

While applied in some nurseries, the value of green-manure crops is contested in others. Concern is being expressed that green-manure crops increase the incidence of soil-born diseases. This will remain an issue difficult to resolve. However, it may be reasonable to assume that green-manure crops fulfill a useful purpose where soil-born diseases do not present an acute problem and that this practice be not applied where diseases are difficult to control.

It should be pointed out that nursery soils of the Atlantic Region tend to be finer in texture and are subjected to a somewhat cooler climate than the typical nursery soil of the Great-Lakes region. Both factors favour organic matter accumulation. Thus, maintaining soil organic matter at a certain level would be cheaper in the Atlantic than Great-Lakes region, assuming that cost of procurement and application of the organic amendment are the same in both regions.

Soil fertility adjustment and maintenance

All of the surveyed nurseries normally adjust soil nutrient levels at the time of seedbed or transplant bed preparation. However, considerable variation exists with respect to rate of application and carriers (type of fertilizer) used (Table 6).

Nitrogen is applied at low levels in some of the nurseries. The only justification for the use of nitrogen at this stage of the rotation is simultaneous organic amendment of soil with a material of high C/N ratio such as peat. Rapid leaching of nitrogen even occurs under these conditions (Davey and Krause, 1980). Thus, application of readily soluble nitrogen fertilizers before sowing or transplanting is an inefficient treatment in most instances and especially if the carrier contains the element in the nitrate form.

Phosphorus is applied at widely varying rates. This is not unreasonable as some of the soils have been farmed for generations and others were cleared from coniferous forest in comparatively recent time. The latter soils have an exceptionally high capacity for phosphorus fixation. To deal with the problem, triple superphosphate has been applied at rates as high as 2000 kg/ha.

Triple superphosphate is the most commonly used phosphorus carrier. Some nursery superintendents have found it convenient to use also, or exclusively, mixed fertilizers such as 0-20-20 or 10-10-10. It should be pointed out that superphosphate also supplies calcium which may compensate to varying degrees for the loss of bases induced by nitrogen and potassium fertilizers. This feature deserves consideration where climatic and geological conditions favour soil acidification as in the Atlantic Region.

Potassium treatments also vary widely with respect to rate of application and carrier used. The explanation given for phosphorus presumably applies here as well, i.e., former agricultural soils with moderate base saturation exhibit better potassium retaining properties and allow for higher fertilization efficiency than recent forest soils (Krause, 1965).

More than one half of the nurseries use sulphate of potash even though this carrier is considerably more expensive than muriate of potash. There is no conclusive evidence in the literature proving the superiority of sulphate of potash over muriate of potash. The preference of the sulphate form probably originates from the early research in Czechoslovakia which suggested that Norway spruce seedlings are sensitive to high levels of chloride in soil. Wilde (1958) warned that muriate of potash may contain toxic levels of borax.

At least two of the nurseries in the Atlantic region have found it necessary to amend soils with readily soluble magnesium. Sulphate of potash and magnesia (sul-po-mag) with a 0-0-22-18 rating, has been used in these cases. The treatments are to counteract the golden-yellow discolouration of needles at the tip of terminal shoots in spruce beds. In pine species, the golden-yellow discolouration shows at the tip of needles. From the so called hard-yellow colour of magnesium deficiency one must distinguish the soft-yellow (orange-yellow) of potassium deficiency (Benzian, 1965).

Sul-po-mag can be an effective remedy where acute deficiency of magnesium is known to exist. However, magnesium deficiency is usually associated with low pH. The best insurance against magnesium deficiency in soils subject to intensive leaching is via pH control. i.e., the use of dolomitic limestone which supplies both calcium and magnesium in optimum proportions.

Fertilizer treatments of seedling and transplant stock

Fertilization schedules and amounts vary considerably with type of stock and nursery (Tables 7 and 8).

Seedling stock is given only a light dressing with nitrogen in two of the nurseries during the first year. Phosphorus and potassium are assumed to have been supplied adequately during seedbed preparation. In the remaining nurseries more than two fertilizer applications are normally made in the first year with maximum cumulative amounts of 212, 105 and 82 kg/ha of nitrogen, phosphorus and potassium, respectively.

In the second year, all but one nursery normally topdress or supply fertilizer via the irrigation system in more than two applications regularly spaced over the growing season. Maximum cumulative amounts

reported in the returns were 313, 164 and 273 kg/ha of nitrogen, phosphorus and potassium, respectively. The highest application rates were reported by nurseries which raised 2+0 stock and which used fertilizers at lower rates at the time of seedbed preparation. Where 3+0 stock was raised, application rates from the second year were maintained or slightly reduced.

Maximum cumulative amounts of nitrogen applied in the first and second year appear to be excessive if compared to recommendations by Armson and Sadreika (1979). Maximum amounts shown for phosphorus and potassium also appear to be excessive, although special soil conditions may justify these rates.

Two of the nurseries reported regular use of magnesium fertilizer in the last one or two years of the rotation to prevent visual symptoms of deficiency from appearing in the fall.

Transplants are normally given the same treatment in both years where 2+2 stock is being raised. Rates of nitrogen applications as used in the different nurseries can vary by a factor of 10. There is a tendency to use phosphorus and potassium at higher rates on transplant than seedbeds. The same nurseries which used magnesium for seedbed treatments also applied the element to transplant beds.

Common Problems

The Atlantic Region lacks the large areas of uniformly textured, level outwash or lake shore deposits common to the Great Lakes Region. Nurseries now in operation are located on till, gravelly outwash terrace or terrain of variable texture and relief.

Some of the nurseries operate on soils with finer than loamy sand texture. Frost heaving is a serious problem under these conditions. To limit damage, seeds are densely sown regardless of whether or not the seedlings are raised for transplanting or field planting. High seedbed density has frequently been the cause of poor quality of stock shipped into the field. It was mentioned earlier that peat mulches are used regularly in most nurseries to counteract frost-heaving.

Erosion hazard was listed by one of the surveyed nurseries as a major problem. Sloping land and medium textured soil have lead to rill erosion with a potential for gulley erosion.

Residual herbicides of the atrazine group have caused a unique problem in new production areas formerly under agricultural use. Seedlings of the first crop were severely stunted and purple in colour. Sections needed to be reseeded where the condition was most severe. This herbicide effect decreased gradually in succeeding crops. Peat addition presumably has had an ameliorating effect in these soils as has the use of activated charcoal. Finally to be mentioned is the occurrence of multiple leaders. This is considered the most serious problem in one of the major bareroot nurseries which culled up to 40% of 2-year-old black and white spruce seedlings before transplanting.

Research

The Province of Nova Scotia has studied fertilization schedules aimed at reducing length of rotation time. An early example of this work is the study by Neily (1977) of fertilizer requirements for optimum development of red pine seedling crops. Extending these investigations from the nursery to the field has indicated that red pine seedlings, raised within two years under an intensive schedule of fertilization, had a reduced potential for survival (Neily 1982). This was attributed to the unfavourable effect of high soil fertility on the shoot/root ratio.

Currently, personnel of the Nova Scotia Department of Lands and Forests are engaged in an assessment of soil moisture characteristics aimed at instituting effective systems of irrigation. Another subject currently receiving attention in this province is the relationship between seedbed density and incidence of frost-heaving. It is aimed to establish lower limits for seedbed density in order to conserve seed, improve quality of stock while frost-heaving is kept at acceptable levels (Neily 1983).

Soil and Plant Analysis

Levels of soil fertility and associated factors are monitored by soil and plant analyses on a regular basis in each nursery. The analyses are

performed separately in each province in different laboratories and, in a number of cases, by different methods. Therefore, standards adopted in one province are not always comparable with those from another province. This, undoubtedly, must hinder progress when and wherever required.

Summary and Conclusions

Planting stock production in the Atlantic Region currently exceeds 80 million trees. New Brunswick is the province with the largest regional output (70%) followed by Nova Scotia (19%), Newfoundland (9%) and Prince Edward Island (2%). The largest producers are the provincial nurseries, contributing 64% to the total regional production. Industrial production comprises 31% of the total output and originates mainly from one nursery. Most of the stock is raised in containers (70%), and about two thirds of the bareroot production is transplant stock. On a regional basis black spruce and jack pine are the major species followed by white spruce and red pine.

Nursery superintendents aim to maintain the pH of soils between 5 and 6. This requires occasional or periodic liming. Target levels for soil organic matter vary between 4.5 and 15% depending partly on the availability of a cheap source of peat. Two of the six nurseries use green-manure crops.

Adjustment of soil fertility, mainly levels of phosphorus and potassium, are an integral part of land preparation for seed and transplant beds in all nurseries. The major portion of fertilizers normally supplied during one rotation is added during the growing seasons in the form of top-dressings or with the irrigation water. The large differences in the amount of fertilizers used in the various nurseries for the preparation of seed and transplant beds, and during the growing season, reflects the variable nature of soils within the region, and probably also differences in views on nursery soil management and crop requirements.

Taking into consideration both amount applied and amount recovered by crops, fertilizer efficiency is generally low in forest nurseries and particularly in one or two of the nurseries included in this survey. Concern is expressed over excessive use of nitrogen. Besides the well-known

effects of high nitrogen availability on shoot-root ratios, amounts supplied in excess over amounts taken up by the plants induce leaching of bases and add to nitrate pollution of groundwater.

A common soil-related problem in nurseries of the Atlantic Region is frost heaving of 1+0 seedlings.

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Table 1. Planting stock production in the Atlantic Region by province and method of propagation†

Province	Bareroot	Container	Total
	Million Trees		
New Brunswick	15.7	41.4	57.1
Nova Scotia	4.1	11.7	15.8
Prince Edward Island	0.5	1.0	1.5
Newfoundland	4.0	3.0	7.0
Atlantic Region Total	24.3	57.1	81.4

† Based on stock shipped or projected for shipment in 1984. Data from Smyth and Brownwright (1984), revised according to results from questionnaire sent to Nursery Superintendents, May 1984.

Table 2. Planting stock production by method of propagation and type of ownership of production facility

Ownership	Bareroot	Container	Total
	Million Trees		
Private	—	3.9	3.9
Industry	9.2	16.1	25.3
Provinces	15.1	37.1	52.2
Total	24.3	57.1	81.4

Table 3. Bareroot production: seedling vs. transplant stock

	Seedlings	Transplants	Total
	Million of Trees		
Province of			
New Brunswick	5.0	1.5	6.5
Nova Scotia	0.5	3.6	4.1
P.E.I.	0.5	--	0.5
Newfoundland	--	4.0	4.0
Industry	2.1	7.1	9.2
Total	8.1	16.2	24.3

Table 4. Ranking of species in order of decreasing quantity of production

Method of Propagation	1	2	3	R 4	a 5	n 6	k 7	8	9	10
Bareroot	bS >	wS >	jP >	bF >	rP >	rS >	wP >	NS =	eL =	Po
Container	bS >	jP >	wS >	rS >	eL >	rP>	bF >	NS >	MISC	
Total	bS >	jP >	wS >	rP >	bF >	rS >	eL>	wP >	NS >	MISC

Table 5. Soil management: pH control

Desired pH 5 - 6

Frequency of Liming	Number of Nurseries
Never	1
Occasionally	3
Periodically	2

Table 6. Levels of soil fertility: adjustment and maintenance

Element	Rates of Application kg/ha	Crriers
Nitrogen	20 - 40	10-10-10, 34-0-0
Phosphorus	50 - 400	Triple Superphosphate 10-10-10, 0-20-20, 9-45-15
Potassium	60 - 250	Sulphate of Potash (0-0-52) Muriate of Potash (0-0-61) Sul-po-mag (0-0-22-18) 10-10-10, 0-20-20, 9-45-15,
Magnesium	11 - 90	Sul-po-mag

Table 7. Fertilizer Treatments of Seedling Stock

Element	Rate of Application (kg/ha)		
	Year 1	Year 2	Year 3†
Nitrogen	19 - 212	28 - 313	28 - 113
Phosphorus	0 - 105	20 - 164	24 - 34
Potassium	0 - 82	47 - 273	47 - 105
Magnesium	--	50	50

† Only three nurseries reported production of 3+0 stock.

Table 8. Fertilizer treatment of transplant stock

Element	Rate of Application (kg/ha)	
	Year 1	Year 2
Nitrogen	28 - 284	28 - 284
Phosphorus	24 - 187	24 - 187
Potassium	47 - 369	47 - 369
Magnesium	55	55

BAREROOT NURSERY SOIL MANAGEMENT DEVELOPMENTS IN BRITISH COLUMBIA

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This talk will deal with two topics. The first concerns:

1. Shoot tip discolouration in interior spruce nursery stock

Over the past 5 years interior spruce (Picea glauca, P. engelmannii and their hybrids) nursery stock has tended to develop straw-coloured apical needles in late July. These frequently become darker brown around the terminal bud later in the season. Nearly all seedlings show slight discolouration, but some are much more severely affected than others. The largest, most rapidly growing seedlings, are frequently the most severely affected. The symptoms have been most noticeable at Surrey and Skimikin nurseries, although not absent from others. Douglas-fir and lodgepole pine in adjacent beds show no evidence of symptoms.

Potassium deficiency was the suspected cause at Surrey nursery and an investigation has been conducted on this assumption. However analysis of samples from Skimikin nursery, by an out-of-Province authority, found as much as 4,000 ppm Mn in seedling tissue, and Mn toxicity was identified as the cause. The critical K level in conifer foliage is usually about 0.4%. The satisfactory level for 22-year old white spruce is given as 0.35% K in current foliage (Heiberg and White 1950) and the normal range in foliage of 2+0 white spruce is given as 0.42 - 0.63 (Armson and Sadreika 1974).

Manganese toxicity is well recorded in the literature with Alfalfa and some Soybeans being notably susceptible. Alfalfa yields drop off when foliar Mn exceeds about 300 ppm. Much higher levels (at least to 1,000 ppm)

are commonly found in conifers (e.g. Beaton et al. 1965). Based on a one month solution culture experiment it has been claimed that 1-year old Douglas-fir seedlings tolerate shoot concentrations of 8,000 ppm Mn without symptoms (Radwan et al. 1979). A longer term sand culture experiment of mine (unpublished) showed that growth decreased when Mn concentration in Douglas-fir seedling shoots was in the range 2,000 - 4,000 ppm.

In a survey at Surrey nursery, seedlings with severe symptoms and with little evidence of symptoms were collected from five seedlots and analysed for all nutrients except Mo (Table 1). The most consistent difference was the lower K concentration in samples showing symptoms. The mean K concentration of 0.59, in seedlings with symptoms, seems quite high on the basis of adequate levels mentioned above. Further analysis has since revealed that upper shoot needles of seedlings showing symptoms average about 0.43% K, but upper shoot needles of healthy seedlings average about 0.61% K.

Magnesium concentration was increased in chlorotic seedlings, possibly because, as a cation, it tended to replace K. Copper concentration was lower in chlorotic seedlings, although the concentration was well above the 2.5 ppm generally considered critical (Oldenkamp and Smilde 1967, Strullu and Bonneau 1978). Manganese tended to accumulate in affected seedlings but not consistently.

In an experiment in which K fertilizer was applied to spruce seedbeds over two years, soil K was increased form 0.28 to 0.86 meq/100 g of dry soil (Figure 1). Unfortunately symptoms were not particularly severe in this area of the nursery (or seedlot), but increased K did reduce symptoms from about 7% to less than 2%. Height was increased a little up to 120 kg K/ha, but reduced again at 240 kg K/ha. Dry weight was not significantly affected by treatment, although the means suggested a slight increase as K level increased. These seedlings clearly responded positively to K fertilization, but why were symptoms not completely eliminated at the 240 kg K/ha level when the height requirement for K was satisfied? Could Mn be involved?

Analysis of most of our commonly used fertilizers showed that most had undetectable levels of Mn, but monammonium phosphate (MAP, 11-55-0)

contained 67 ppm Mn and dolomitic limestone contained 470 ppm. Thus, dressings of 1,000 kg/ha dolomitic limestone added 450 g Mn/ha about once every two year rotation, and MAP dressings perhaps a further 40 g. Peat amendments, according to source, also contained from 30 to 130 ppm Mn. Manganese was therefore likely to be readily available in the acid (pH 4.5 - 5.5) nursery soil.

Periodic sampling of one spruce seedlot during the second year showed that foliar Mn concentration increased from about 300 ppm in May to about 2,500 in December (Figure 2). In fact, these seedlings did not show particularly severe tip discolouration. To further study Mn uptake, hydrated lime [$Ca(OH)_2$] and MAP were both applied at two levels to 2+1 spruce in a factorial experiment (Table 2). As expected, addition of lime reduced Mn uptake and addition of MAP promoted Mn uptake by the transplants. Again, although chlorotic plants usually contained more Mn than healthy plants this was not consistently true. Furthermore, these transplants showed pronounced shoot chlorosis, yet their Mn level in no case exceeded 2,000 ppm. On the other hand, healthy plants showed a consistently higher K concentration than chlorotic plants (Table 3) and MAP significantly depressed K concentration. Differences in Cu concentrations between healthy and chlorotic plants were small, or non-existent.

The evidence suggests K deficiency despite the relatively high foliar K concentrations and K fertilizer application of about 200 kg K/ha per rotation. As previously shown (Krause 1965), K can be rapidly leached from acid sandy soil and is presumably being lost sufficiently fast to cause symptoms on interior spruce. Evidently Douglas-fir and lodgepole pine either do not have such high K requirements or else are less sensitive to deficiency as they do not show symptoms.

2. Use of slow release fertilizers in the nursery.

At different times five slow-release fertilizers have been examined and compared with MAP, ammonium sulphate and Hisol (Table 4). White spruce transplants (2+1) were grown in peat/sand/soil mixture contained in gallon pots. The plants were outside and received one of five slow release N treatments, supplying 4.2 g N per pot (1,000 kg N/ha). An untreated control was included (Figure 3). Amongst the fertilizers, greatest growth, after one season, was obtained with Osmocote and least with IBDU, but IBDU treated trees made significantly more growth than controls.

Pots were leached with water in July and August and litre of leachate was collected to determine the relative availability of nutrients (Figure 3). Agriform released more P than any other fertilizer and leachate pH ranged from 5.5. and 5.7 in the slower growing control and IBDU treatments to 4.7 and 4.9 in the SCU and urea formaldehyde treatments. Judging from leachate concentrations release of N by fertilizers was:

SCU > URFO > OSMO > AGRI > IBDU > CONT

Ammonium may have been adsorbed in the growing medium so that less appeared in the leachate, whereas most of the nitrate would appear in the leachate (Figure 4). Spruce transplant growth was not obviously correlated with availability of water soluble N or P.

Both Douglas-fir and white spruce 2+0 seedlings showed similar growth response to fertilizers at Surrey nursery (Figure 5). Fertilizers were applied once in year 1 and once in year 2, except for ammonium sulphate which was applied 6 times each year. All fertilizers were applied at four levels: (1) 0, (2) 70, (3) 140 and (4) 210 kg N/ha, but levels have been averaged for presentation here. Ammonium phosphate and ammonium sulphate resulted in greatest growth and the slow release fertilizers least.

Neither available soil NH_4^+ nor available soil P showed any correlation with growth. Soil nitrate showed some correlation with Douglas-fir seedling dry weight ($r^2 = 0.24$), but soil pH accounted for almost 70% ($r^2 = 0.69$) of the variation in seedling dry weight in this experiment (Figures 6 and 7).

Greater growth of white spruce at Surrey nursery was also obtained with ammonium sulphate and ammonium phosphate when these were compared with Osmocote and a highly soluble (Hisol) fertilizer (Figure 8). Ammonium sulphate and Hisol were applied frequently, Osmocote and ammonium phosphate once each year. Thus solubility and frequency of application appeared relatively unimportant influences on spruce growth. Here again, although regression analysis has not yet been done, it appears that growth is better correlated with soil pH (Figure 9) than with available soil N.

Results from these experiments suggest that changes in soil pH brought about by various fertilizers are as important for growth as the availability of the nutrients they supply. At Surrey nursery ammonium

sulphate and ammonium phosphate promoted more growth than SCU and Osmocote. Osmocote is a complete fertilizer and might be useful for this reason, but as a slow release N source SCU, which costs one quarter as much as Osmocote per kg N, and is cheaper than MAP per kg N, appears potentially the most useful of the slow release fertilizers.

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Table 1. Average analyses for white spruce foliage of five seedlots separated into healthy and chlorotic (20 plants per sample)

2+0 and 2+1 Spruce Needles

	N	P	K	Ca	Mg	S
			%			
Healthy	2.4	0.24	0.70	0.73	0.12	0.19
Chlorotic	2.4	0.27	0.59	0.87	0.15	0.19
	NS	NS	*	NS	*	NS
	Cu	Fe	Mn	Zn	B	
			ppm			
Healthy	6.3	199	1709	43	26	
Chlorotic	5.4	212	2311	47	31	
	*		NS			

* Difference between healthy and chlorotic means significat at p = 0.05.
NS Healthy and chlorotic means not significantly different.

Table 2. White spruce transplant needle Mn concentration shown by condition, lime and monammonium phosphate concentration

Condition of 2+1 Spruce	Lime kg/ha			
	0		100	
	MAP kg P/ha			
	0	400	0	400
	Needle Mn ppm			
Healthy	1314	1884	1218	1559
Chlorotic	1771	1809	1378	1715
	1542	1846	1298	1637

Table 3. White spruce transplant needle K and Cu concentration shown by condition, lime and monammonium phosphate concentration

Condition of 2+1 Spruce	Lime kg/ha			
	0		1,000	
	Map kg P/ha			
	0	400	0	400
	Needle K%			
Healthy	0.67	0.61	0.68	0.61
Chlorotic	0.53	0.51	0.51	0.48
	Needle Cu ppm			
Healthy	4.5	4.0	4.1	4.3
Chlorotic	4.0	4.3	4.1	3.9

Table 4. Fertilizers of different release rates and their costs

	Fertilizer	Analysis	$/Kg	
			Fert.	N
1	Isobutylidene Diurea	31-0-0		
2	Agriform	20-10-5	4.19	20.95
3	Osmocote	18-5-11	2.07	11.50
4	Urea formaldehyde	38-0-0	1.03	2.71
5	Sluphur coated urea	32-0-0	.90	2.81
6	Ammonium phosphate	11-55-0	.45	4.09
7	Ammonium sulphate	21-0-0	.30	1.42
8	Hisol	20-20-20	2.14	10.70

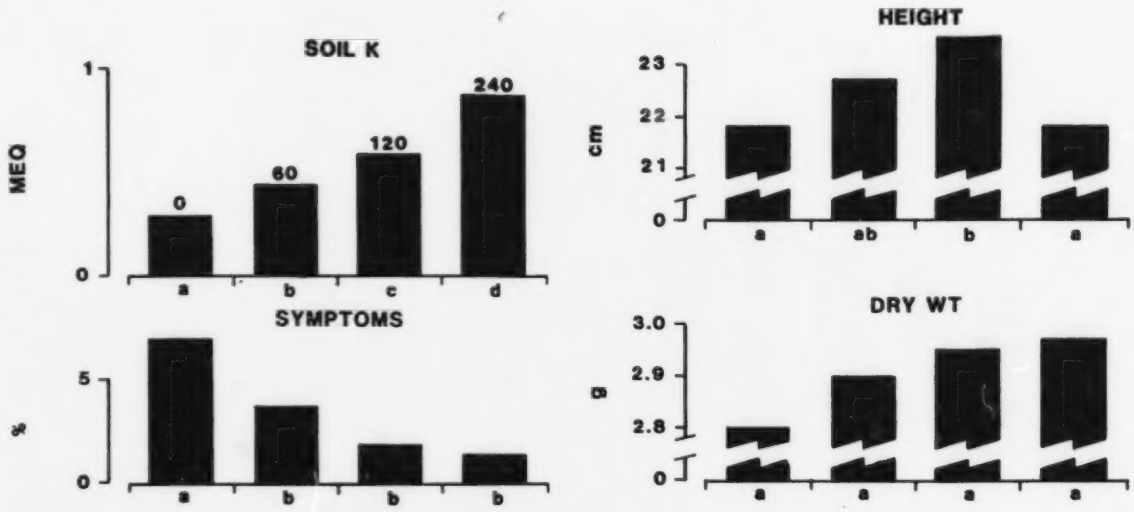

Figure 1. K treatment kg/ha.

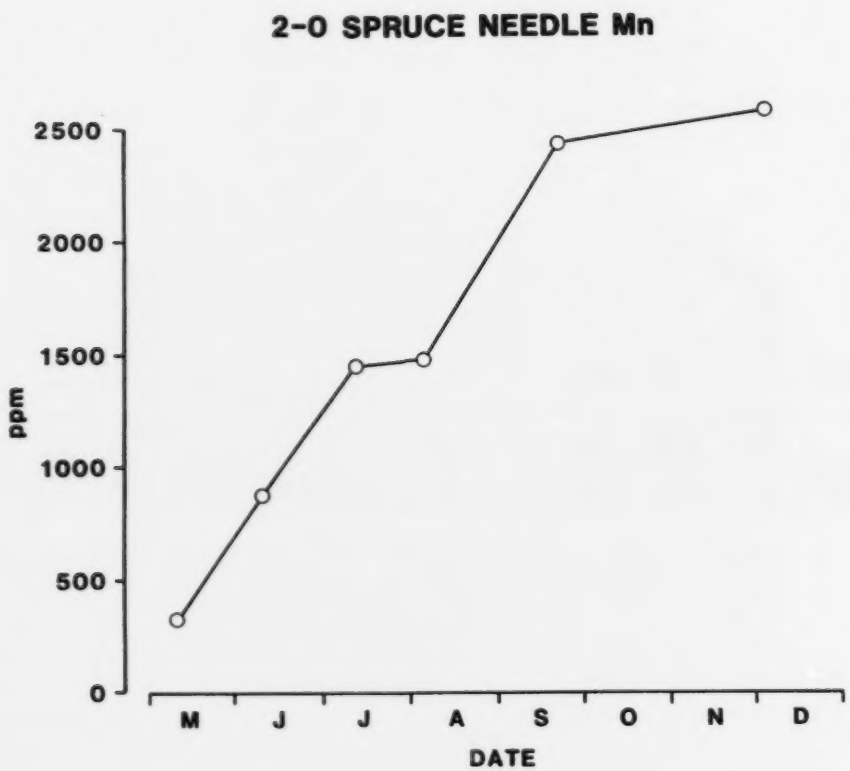

Figure 2. 2+0 spruce needle Mn.

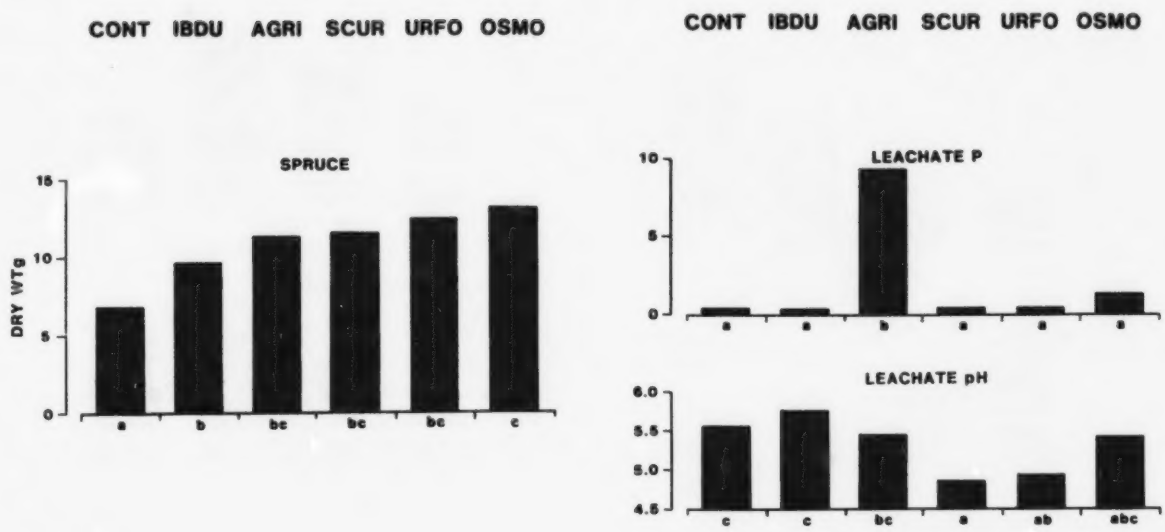

Figure 3. Seedling & Soil response to fertilization.

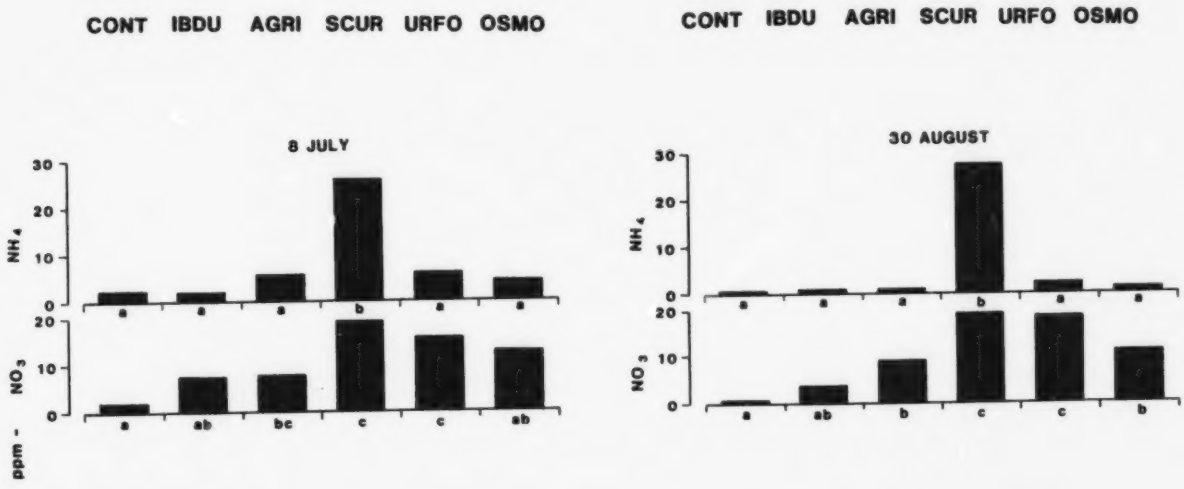

Figure 4. Soil response to fertilization.

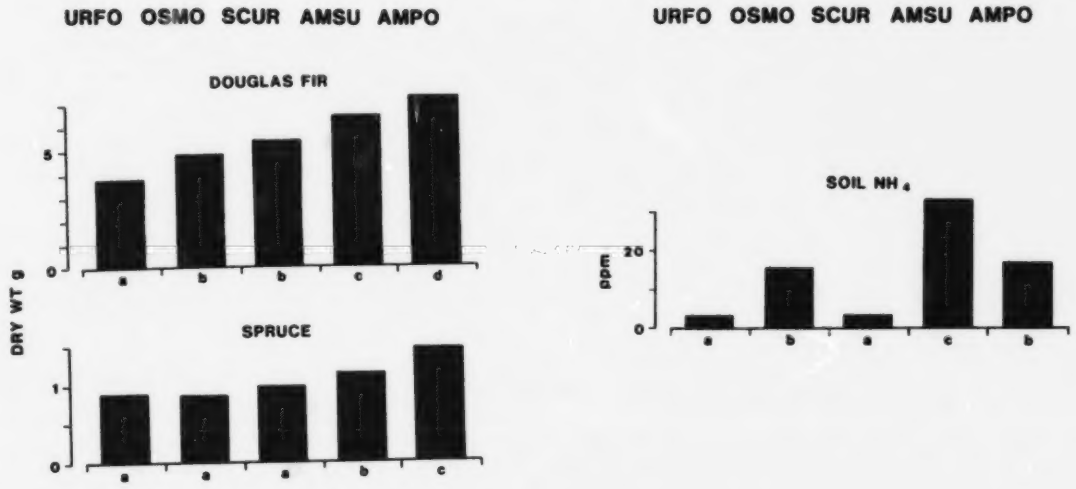

Figure 5. Seedling & Soil response to fertilization.

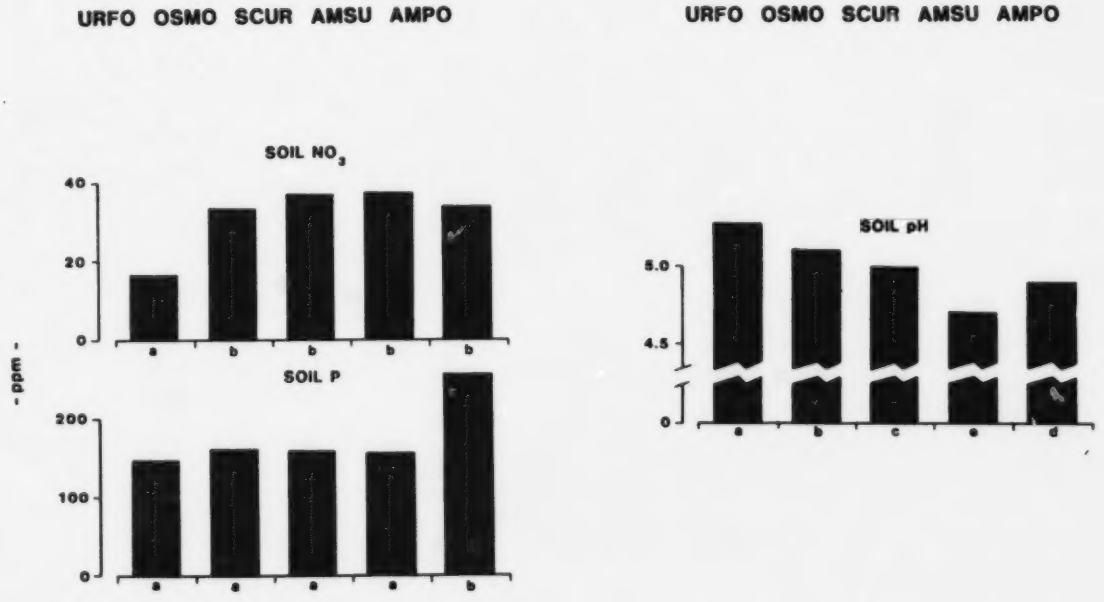

Figure 6. Soil response to fertilization.

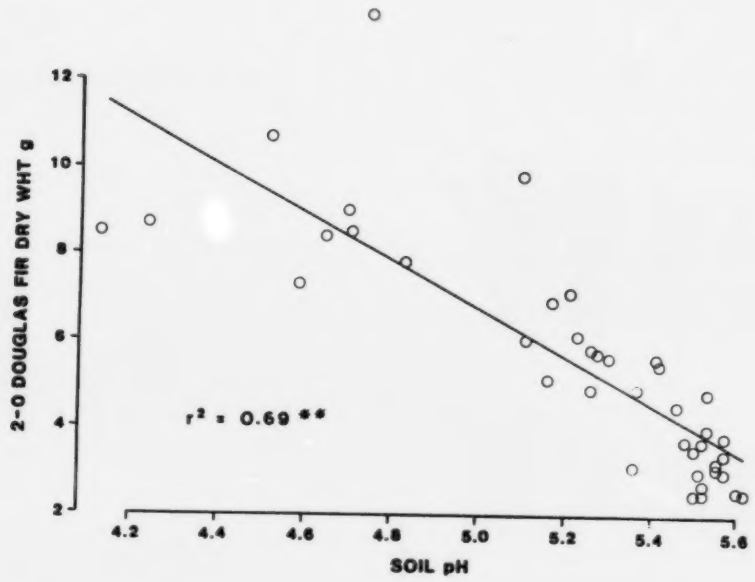

Figure 7. 2+0 Douglas-Fir dry wht. (g) and pH.

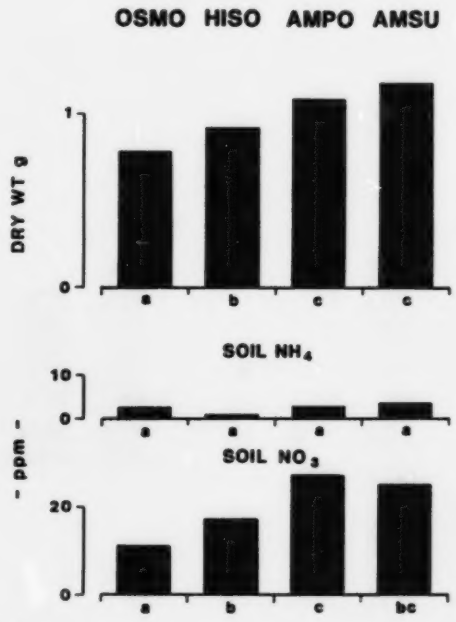

Figure 8. Seedling & Soil response to fertilization.

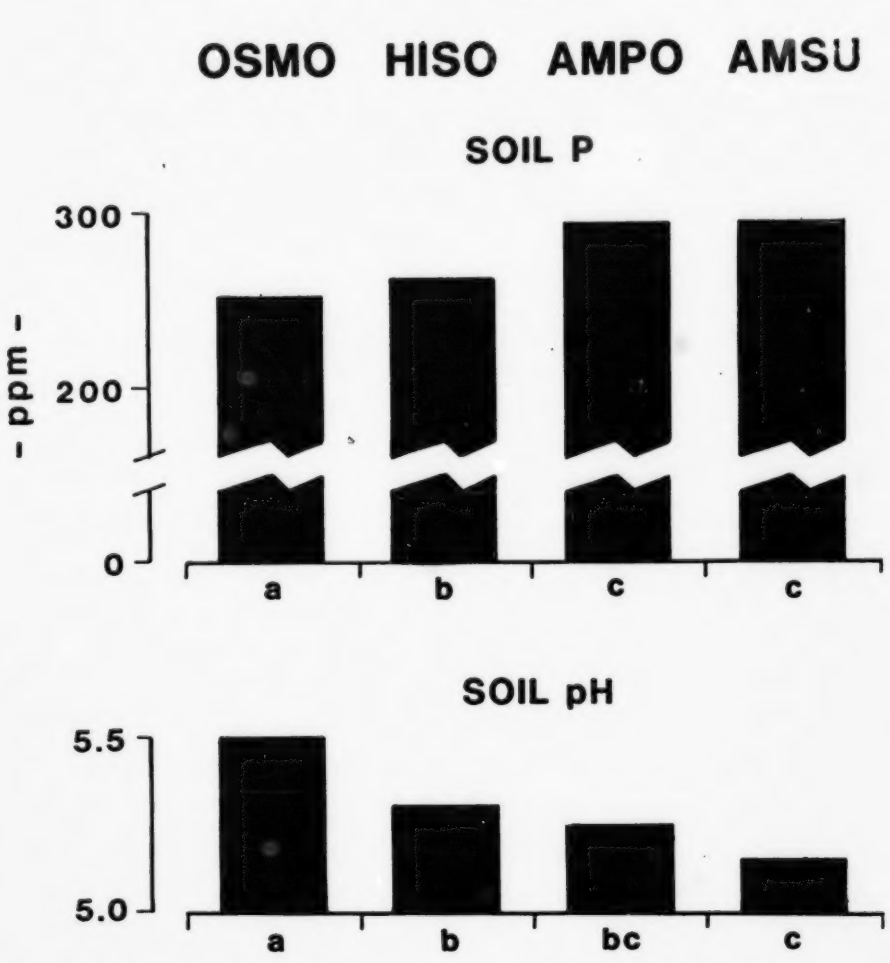

Figure 9. Soil response to fertilization.

MORPHOLOGICAL AND PHYSIOLOGICAL STOCK QUALITY IN RELATION TO FIELD OUTPLANTING PERFORMANCE (1982-83 RESULTS)

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ABSTRACT

Research was initiated in 1981 and continued in 1982 to measure the morphological and physiological attributes of Picea glauca (Moench) Voss and Picea mariana Mill. (B.S.P.) $1^1/2+1^1/2$ transplant and Pinus banksiana Lamb. 2+0 seedling nursery stock as a possible means of predicting performance after outplanting. The results of the first years work in 1981 are reviewed and discussed. The results of the research initiated in 1982, the second year of study, are summarized and discussed.

In the fall of 1981 and spring of 1982 the stock was subjected to the following lifting and storage treatments: 1) Spring lifted and planted one week after lifting, 2) Spring lifted and cold stored at $+2 \pm 1°C$ at $-2 \pm 1°C$ before planting, 3) Fall lifted and overwinter frozen stored at $-2 \pm 1°C$ before planting, 4) Fall lifted and stored as in 3, but conditioned at $+2 \pm 1°C$ for 3 to 6 weeks before planting, and 5) Fall lifted and packed vertically in boxes over moist peat moss and stored in the light at $-2 \pm 1°C$ for one month before placement in overwinter storage at $-2 \pm 1°C$ before planting. In the spring of 1982 the stock was measured, planted in pots in a standard environment in growth chambers and concurrently outplanted on sandy outwash and till field sites on May 4, May 25 and June 15, 1982.

The morphological quality of the stock was determined by standard methods (Day 1980). The physiological quality of the stock was judged from its Root Regeneration Potential (RRP) by measuring its Root Elongation (RE) and Total Root Number (Total RN) over a 21-day test period. The field

performance of the stock was assessed by evaluating its percent survival, Physical Condition (PHCC) and Height growth (HG) at the end of the first (1982) and second (1983) growing seasons.

The results of the morphological quality testing showed that the stock was average or slightly smaller than average (Day 1980). Stock lifted in the fall of 1981 with the Ontario Seedling Harvester for over-winter storage suffered more root loss than the same stock lifted with the Egedal Shaker in the spring of 1982.

The results of the 21-day physiological quality tests showed that: 1) stock commonly looses from 22 to 32% of its initial Root Area Index (RAI) over the 21-day test period, 2) RE and total RN are the best measures of RRP, and 3) Picea mariana regenerates considerably more root than either Picea glauca or Pinus banksiana.

The results of the laboratory and field trials showed that: 1) RRP measured in the laboratory over a 21-day period in 1982 was approximately similar to RRP in the field over the same period (Day and Harvey 1983), 2) RRP measured in the laboratory in 1982 helped to predict percent survival and Height Growth in the field at the end of the first (1982) and second (1983) growing seasons, and 3) the minimum amount of RE and Total RN needed for successful establishment of Picea glauca is >35 and >35, for Picea mariana is >50 and >99, and for Pinus banksiana is >35 and >30 respectively.

Introduction

In 1980 a program of research was initiated to investigate the relationship between the morphological and physiological quality of nursery stock measured in laboratory tests and its performance after outplanting on cutover land in the Boreal Forest (Day and Harvey 1983). The research was conducted under the auspices of the Ontario Ministry of Natural Resources (OMNR) and was supported by the Canada Department of Regional and Economic Expansion (DREE). The following outline briefly describes the sequence of laboratory and field work.

Sequence of Research Program

Research in 1980-1981

1) Evaluation of the Morphological and Physiological Quality of stock lifted in the fall of 1980 and spring of 1981 in Laboratory Tests and Field Trials carried out in the spring and summer of 1981.

2) Evaluation of the Performance of the stock outplanted in 1981 in Field Trials at the end of its First Growing Season in the fall of 1981.

Research in 1981-1982

3) Evaluation of the Morphological and Physiological Quality of stock lifted in the fall of 1981 and spring of 1982 in Laboratory Tests and Field Trials carried in the spring and summer of 1982.

4) Evaluation of the Performance of the stock outplanted in 1982 in Field Trials at the end of its Second Growing Season in the fall of 1982.

5) Evaluation of the Performance of the stock outplanted in 1981 in Field Trials at the end of its Second Growing Season in the fall of 1982.

Research in 1982-1883

6) Evaluation of the Morphological and Physiological Quality of stock lifted in the fall of 1982 and spring of 1983 in Laboratory Tests and Field Trials carried out in the spring and summer of 1983.

7) Evaluation of the Performance of the stock outplanted in 1983 in Field Trials at the end of its First Growing Season in the fall of 1983.

8) Evaluation of the Performance of the stock outplanted in 1982 in Field Trials at the end of its Second Growing Season in the fall of 1983.

9) Evaluation of the Performance of the stock outplanted in 1981 in Field Trials at the end of its Third Growing Season in the fall of 1983.

The research programme described above was designed to measure morphological and physiological attributes of $1^1/2+1^1/2$ white spruce (Picea glauca [Moench] Voss) and black spruce (Picea mariana Mill. B.S.P.) transplants and 2+0 jack pine (Pinus banksiana Lamb.) seedlings and to relate these measures to survival, condition and height growth the first, second and third growing seasons after outplanting.

If all measurements are to be completed to the third year, it is obvious that the above schedule will have to be extended to 1985. In 1984, it will be essential to evaluate the performance of stock outplanted in 1982 (third year results) and 1983 (second year results). In 1985, it will be essential to evaluate the performance of stock outplanted in 1983 (third year results).

The results of the evaluation of morphological and physiological quality of the stock in 1981 (Item 1 above) and of the subsequent measurements of its performance in the field in 1981 and 1982 (Items 2 and 5 above) are fully reported in Day and Harvey (1983). These results may be briefly summarized as follows.

In 1980-81 the nursery stock was subjected to the following lifting and storage treatments before it was measured, planted in pots in growth chambers and concurrently planted at sandy and till field sites on May 4, May 25 and June 15, 1981: 1) spring lifted and planted one week after lifting, 2) spring lifted and cold stored at $+2 \pm 1$°C for 21 days, 3) fall lifted and frozen stored at -2 ± 1°C over winter, and 4) fall lifted and frozen stored at -2 ± 1°C over winter as in 3, but conditioned at $+2 \pm 1$°Cfor 21 and 42 days.

In 1980-81, the morphological quality of the stock was determined by methods described in (Day 1980). The physiological quality of the stock was judged by evaluating its Root Regeneration Potential (RRP) over a 21-day test period. The principal measures of RRP were Root Elongation (RE) in cm and Total and Long Root Number (Total and Long RN). Root Area Index (RAI)

in cm^2 was also measured to evaluate gross change in root system size over the 21-day test period. The field performance of the stock was evaluated by recording its percent survival, Physical Condition Code (PHCC) and Height Growth (HG) at the end of the growing season.

The results of the morphological quality testing in 1981 showed that the seedlings were of average or slightly less than average size. Stock that had been fall lifted with the Ontario Belt Harvester had considerably smaller root systems than stock lifted in the spring with the Egedal Shaker. The Ontario Belt Harvester was less efficient than the Egedal Shaker in retrieving seedling root systems.

The results of the RRP tests showed that: 1) RE and Total RN are the best measures for evaluating RRP, 2) as an average of up to 16 cm^2 of RAI may be lost per seedling over 21-days, RAI is not an effective measure of RRP but is an effective measure of the proportion of roots lost after outplanting, 3) black spruce transplants consistently regenerate more new roots after outplanting than either white spruce transplants or jack pine seedlings, 4) there was considerable variation between both individual seedlings and treatment means in the RRP of the three species tested, 5) the 21-day RRP tests carried out in the growth chambers adequately predicted the 21-day RRP results measured in the field.

The field performance results at the end of the first and second growing seasons in 1981 and 1982 indicated that: 1) jack pine seedlings had greater height growth than either white or black spruce transplants during the first two years after outplanting, 2) there were no statistically acceptable correlations between RE or total RN at 21-days in the growth chamber with percent survival, PHCC or HG at the end of either the first or second growing seasons, although there were similar trends, 3) zero values for RE and Total RN at 21-days in the growth chamber predicted low percent survival and poor PHCC in the field at the end of the first and second growing seasons, but did not predict the mean HG of <u>surviving</u> seedlings, and 4) the mean HG at the end of the second growing season was found to be a more valuable indicator of field performance than at the end of the first growing season.

The handling associated with making pre-planting (x) measurements of RE and total RN at 21-days may have resulted in damage to the seedlings. This may account for the poor correlations between RE and total RN at 21-days in the growth chamber tests and percent survival, PHCC and HG in the field at the end of the first and second growing seasons.

The results of the evaluation of morphological quality and physiological quality of stock in 1982 and of the subsequent measurements of its performance in the field in 1982 and 1983 are the subject of this paper. In 1982 a number of changes were made to improve the methodology and analysis of data. The most important of these were: 1) the elimination of the initial (x) measurements of the stock which were thought to be detrimental in 1981, and 2) the use of Spearman's Rank Correlation Co-efficient, a non-parametric statistical test, to show that there were statistically acceptable correlations between RE and Total RN at 21-days in the growth chamber with those at 21 days in the field and also with percent survival, PHCC and HG in the field at the end of both the first and second growing seasons.

Objectives

To prepare test lots of $1^1/2+1^1/2$ white and black spruce (Picea glauca [Moench] Voss) and (Picea mariana [Mill] B.S.P.) and 2+0 jack pine (Pinus banksiana Lamb.) nursery stock by varying lifting date and storage treatment [i.e. (1) Spring Lifted, (2) Spring Lifted and Cold Stored at $+2 \pm 1°C$, (3) Fall Lifted and Frozen Stored at $-2 \pm 1°C$, and (4) Fall Lifted and Frozen Stored [in the light or dark] at $-2 \pm 1°C$, but conditioned at $+2 \pm 1°C$].

To plant test lots of stock over a period in the spring and early summer of 1982 (i.e. 1] May 4, 2] May 25, and 3] June 15) both in pots in a standard growth chamber environment and field outplanting trials.

To measure the morphological quality of each stock lot before planting.

To test and compare the physiological quality of each stock lot before and after planting and to compare and correlate these measurements with survival, physical condition and height growth at the end of the first and second growing seasons.

To determine whether results from the growth chamber tests can be used to predict outplanting performance in the field.

METHODS

Study Locations

The Thunder Bay Forest Station which is located 20 kilometres west of Thunder Bay, Ontario, supplied the nursery stock and provided cold ($+2 \pm 1°C$) and frozen ($-2 \pm 1°C$) storage facilities. Stock handling, measurement and testing was done at the laboratories, and in the growth chambers of Lakehead University at Thunder Bay, Ontario.

Two field planting sites were selected 80 km north of Thunder Bay at approximately 48° 51'N, 89° 15'W on the Ontario Ministry of Natural Resources, Thunder Bay District, Port Arthur Management Unit. The field sites were chosen on sandy outwash and ground moraine land types (Zoltai 1963 and 1965), two dissimilar but commonly occurring landforms in the region. Approximately 2.6 hectares were planted at each site.

Treatments

Thirteen treatments were tested in controlled environment chambers and outplanted at the field sites in 1982 (Table 1).

The treatments which were applied to each species individually are described in detail below:

1) Spring Lifted and Planted 1 Week after Lifting. The stock was lifted on these dates, April 27, May 18 and June 8, 1982 and planted 7 days later on May 4, May 25 and June 15. The delay of one week between lifting and planting allowed time for measurement and simulated an average grading, packing and transport delay.

2) Spring Lifted and Cold Stored at $+2 \pm 1°C$ for 21 days. The stock was lifted on two dates May 4 and May 23, 1982 and placed in cold storage ($+2 \pm 1°C$) for 21 days. The stock was then planted on May 25 and June 15. The delay of three weeks between lifting and planting was designed to simulate short spring storage. Measurements were made one week before planting.

3) Fall Lifted and Frozen Stored at $-2 \pm 1°C$. The stock was lifted in late October 1981. It was packed in sealed polyethylene bags in waxed Kraft boxes and maintained at $-2 \pm 1°C$ at the Thunder Bay Forest Station. It was measured during the winter of 1981-82 and planted on May 4 and June 15, 1982. This treatment is standard for overwinter stored stock.

4) Fall Lifted Frozen Stored at $-2 \pm 1°C$ and Conditioned at $+2 \pm 1°C$ for 21 and 42 days. The stock was lifted in late October 1981 (identical to 3 above). It was packed in sealed polyethylene bags in waxed Kraft boxes and maintained at $-2 \pm 1°C$ at the Thunder Bay Forest Station. It was measured during the winter of 1981-82 and then divided into four lots for conditioning for 21 and 42 days at $+2 \pm 1°C$ before planting as follows in 1982:

Treatment	Date Transferred from Cold Storage at $-2 \pm 1°C$ to $+2 \pm 1°C$	Date Planted
Q	March 23	May 4
M	April 13	May 4
R	April 13	May 25
N	May 5	May 25

5) Fall Lifted Frozen Stored $-2 \pm 1°C$ Packed Vertically in Moss Under Light for One Month and then Frozen Stored Over winter as in 4. Conditioned at $+2 \pm 1°C$ for Three and Six Weeks. The stock was lifted in late October 1981 (identical to 3 and 4 above). It was packed vertically in moss on November 18 and stored in a frozen $-2 \pm 1°C$ greenhouse for one month. It was then packed in sealed polyethylene bags in waxed Kraft boxes (identical to 3 and 4 above) and maintained over winter at $-2 \pm 1°C$ at the Thunder Bay Forest Station. The stock was then measured one week before planting on May 25, 1982.

Experimental Design

1. The Growth Chamber Test

A 13 treatment x 5 replication random block experimental design was used to investigate the response of each species of stock subjected to the various treatments in the growth chambers in 1982.

A replication was composed of 5 measured seedlings planted in a 50:50 peat-vermiculte mix in a 23 cm diameter bulb pan. Thus during the course of the experiment in 1982, 5 seedlings x 5 replications x 13 treatments x 3 species = 975 seedlings or 195 bulb pans were grown in the growth chambers for 21 days.

2. Field Outplanting Trials

A 12 treatment x 3 replication random block experimental design was used to evaluate the performance of each species of stock subjected to various treatments on each outplanting site in 1982. In the field outplanting trials the number of treatments was reduced to 12 by eliminating Treatment V. There were not sufficient seedlings in Treatment V to outplant any white spruce, and black spruce and jack pine could only be planted on the field sandy outwash site.

A replication was composed of 50 seedlings, 15 measured and 35 non-measured. The species were planted in the field in a single randomized block design. Within each species there were 3 replications x 12 or 13 treatments x 50 seedlings (15 measured seedlings) = 1,800 or 1,950 seedlings (540 or 585 measured seedlings) per planting site. A total of from 10,800 to 11,700 seedlings (3,240 to 3,510 measured seedlings) were planted in 1982.

Seedling Measurement

The following x measurements were made on each measured seedling prior to planting to describe physiological and morphological quality of the seedlings planted in the pot trial and at the two field sites.

1) Total Height (Ht) in cm,
2) Root Collar Diameter (RCD) in mm,
3) Height Growth (HG) in cm,
4) Physical Condition Code (PHCC),
5) Phenological Condition Code of the Shoots (PCCS),
6) Root Area Index (RAI) cm^2.

After planting, the seedlings were allowed to grow for a 21-day Root Regeneration Potential (RRP) period. After 21 days all of the seedlings in the growth chamber and the 15 measured seedlings from each plot in the field planting sites were excavated.

The following y measurements were made on each measured seedling after the 21-day test period to describe physiological and morphological quality.

1) Height Growth (HG) in cm,
2) Physical Condition Code (PHCC),
3) Phenological Condition Code of the Shoots (PCCS),
4) Root Area Index (RAI) in cm^2,
5) Root Number Code (RN) and Elongation (RE) of small root tips (> 0.0 to 2.0 mm),
6) Root Number Code (RN) and Elongation (RE) of medium root tips (> 2.0 to 10.0 mm),
7) Root Number Code (RN) and Elongation (RE) of long root tips (> 10.0 mm)

At the end of the first and second growing seasons in 1982 and 1983 the percent survival was determined and the following measurements were made on unmeasured seedlings on each plot at both field planting sites.

1) Height Growth (HG) in cm,
2) Physical Condition Code (PHCC),
3) Shoot Growth Potential Code (SGP).

It is hoped that these seedlings will be evaluated one more time at the end of the growing season in 1984.

Statistical Analysis

All analysis was done on the Lakehead University Digital Equipment Corporation's VAX computer using Fortran programs.

1) Morphological Quality

Mean Ht, RCD and initial (x) RAI values were subjected to Analyses of Variance (ANOVA) (Steele and Torrie 1960) to determine if there were significant differences in the morphological quality of the stock treatments. When ANOVA showed that there were significant differences between treatment means, a Student-Newman-Keul's test (SNK test) (Steele and Torrie 1960) was applied to evaluate them.

Mean Ht, RCD and initial (x) RAI were used to classify the morphological quality of the stock according to the Mean and Standard Deviation Method (MSD Method) defined by Day (1980).

2) Physiological Quality and Growth Chamber and Field Performance - 21 day test

The difference between initial and final RAI for individual seedlings was computed. These values were entered into 7 frequency classes for RAI increment or decrement over 21 days as follows:

Class	RAI Increment-Decrement (cm^2)
1	> +7.5
2	+4.6 to + 7.5
3	+1.6 to + 4.5
4	-1.4 to + 1.5
5	-4.4 to - 1.5
6	-7.5 to - 4.5
7	< -7.5

The percentage of seedlings in each class was calculated.

The RE due to small and medium and long roots was computed for each seedling over the 21 day RRP period. The total RE for each individual seedling was entered into 6 frequency classes as follows:

Class	R.E. (cm)
1	> 50
2	26 to 50
3	11 to 25
4	5 to 10
5	1 to 5
6	0 to 1

The percentage of seedlings in each class was calculated.

The Long RN for each seedling was computed and entered into 6 frequency classes as follows:

Class	# of long of roots
1	> 50
2	26 to 50
3	11 to 25
4	6 to 10
5	1 to 5
6	0 to 1

The percentage of seedlings in each class was calculated.

Individual seedling values for the RNK of Small and medium roots and the RN of long roots were integrated to estimate total RN. Individual values for the RE of Small, Medium and Long roots were integrated to estimate the RE. Individual seedling values for RAI increment or decrement and RE, Long RN and Total RN were subjected to Covariance Analyses (COVAR) using a randomized complete block design with subsamples (Steele and Torrie 1960). Mean percent survival values were transformed using the method arcsin (Steele and Torrie 1960). The transformed values were subjected to COVAR using a randomized complete block design. All data was tested using initial (x) RAI as a covariate. Finney's (1946) method for estimating an average value for the contribution of the x variable into the variance was used to calculate the effective residual mean square. This value was used to determine if there was an increase in accuracy due to COVAR using the method outlined by Cochran and Cox (1957). If no accuracy was gained with COVAR, ANOVA was conducted. When ANOVA or COVAR showed that there were significant differences between the treatments, SNK tests were applied (Steele and Torrie 1960). When ANOVA was used, actual treatment means were compared to determine the significance of the difference between individual treatment means. When COVAR was used, treatment means were adjusted and compared using Finney's (1946) method.

The treatment means of the 21-day test for values of RE, Long RN and Total RN from the Laboratory Pot Trial were ranked and compared to the ranked means for these attributes from each of the two Field Sites using the Spearman Rank Correlation Coefficient (SRCC) (Siegel 1956, Sokal and Rohlf 1981).

3) Field Performance - first and second year

Individual seedling values for PHCC were subjected to ANOVA using a randomized complete block design with subsamples (Steele and Torrie 1960). Values for mean HG per plot of surviving seedlings were subjected to ANOVA using a randomized complete block design. Mean percent survival values were transformed using the method arcsin (Steele and Torrie 1960). The transformed values were also subjected to ANOVA using a randomized complete block design. When ANOVA showed that there were significant differences between the treatments, SNK tests were applied (Steele and Torrie 1960).

The treatment means of the 21-day test values of RE and Total RN from the Laboratory Pot Trial were ranked and compared to the ranked means for percent survival, PHCC and HG at the two Field Sites using the SRCC (Siegal 1956, Sokal and Rohlf 1981).

Weather Data Collection

One two-point remote recording soil thermograph was placed at each of the two planting sites in a typical seedling microsite in mid-May when the soil had thawed out sufficiently to allow placement of the probes. These thermographs each have 2 soil probes which were placed at 10 cm and 20 cm in depth in order to record the soil temperature in the seedling rooting zone. The charts on these thermographs were changed weekly and the average temperature recorded between the 4 probes was used to calculate the mean weekly soil temperature. Air temperature and humidity was recorded using hygrothermograph placed in a Stevenson screen at the field sandy outwash site. This chart was also changed weekly. A rain gauge was used to measure the total weekly precipitation.

SUMMARY OF RESULTS AND DISCUSSION

The following summary of results and discussion is taken from Day and Harvey 1984.

Tables 2, 3 and 4 present the RRP test results determined in the Laboratory Pot Trial in 1982 and the 'Outplanting Success Indices' (OSIs) for 1982 and 1983 determined by integrating 'Treatment Success Codes' (TSCs) for both percent survival and Height Growth. The OSIs were developed as follows:

1) The percent survival was classified into the following TSCs: 0 = 0, 1 = 1 to 20, 2 = 21 to 40, 3 = 41 to 60, 4 = 61 to 80, and 5 = 81 to 100 percent survival.

2) The HG was classified in the following TSCs: 0 = 0, 1 = 1 to 20, 2 = 21 to 40, 3 = 41 to 60, 4 = 61 to 80, and 5 = 81 to 100 percent of the maximum HG of each species in the best treatment each year.

3) The TSC values for percent survival and HG (1 and 2 above) were summed to produce each OSI value. For example, Table 2 shows that in 1982 Treatment 1 had a TSC of 4.5 for survival and 3.0 for Height Growth = an OSI of 7.5; in 1983 the TSCs were 2.5 and 3.0 = an OSI of 5.5.

In order to interpret the OSIs, the following performance classification is suggested:

Performance Rating	OSI Range
Very High	9.0 to 10.0
High	8.0 to 8.9
Medium	7.0 to 7.9
Low	6.0 to 6.9
Very Low	5.0 to 5.9
Failure	<5.0

In the sections that follow the OSI ratings determined at the end of the second growing season in 1983 will be mainly discussed because they are of greater importance than those for 1982.

White Spruce

The $1^1/2+1^1/2$ white spruce stock had OSIs ranging from 10.0 or Very High, to 5.5 or Very Low in 1983 (Table 2).

Stock Lifted in the Spring of 1982. Treatments A, B and E had Very High OSI values. Treatments A and E which were lifted before the onset of growth both had OSI values of 10.0 even though Treatment E was held in cold storage at +2°C for three weeks before outplanting.

Treatment B which was lifted with the buds beginning to flush three weeks after Treatments A and E performed nearly as well with a Very High OSI value of 9.5. Treatment G which was lifted at the same time as Treatment B, but was cold stored at +2°C for three weeks, performed almost a well as A, B and E with an OSI value of 8.0 or High. Treatment C which was lifted in full flush six weeks after Treatments A and E and outplanted directly did not perform well only achieving an OSI of 5.5 or Very Low.

Stock Lifted in the Fall of 1981 and Overwinter Stored at -2°C. Treatments I and K which were planted directly from frozen storage on May 4 and June 15 had OSI values of 5.5 or Very Low, and 9.5 or Very High, respectively. The difference between Treatments I and K is hard to explain as they are essentially the same stock, except that Treatment K had been kept six weeks longer in frozen storage. It seems probable that low soil temperatures in May were adverse for the establishment of Treatment I,

whereas the high soil temperatures in June and July and heavy precipitation in July enhanced the establishment of Treatment K. Treatments M and N which were conditioned for three weeks at +2 $\pm$ 1°C before outplanting on May 4 and 25 respectively had OSI values of 5.5 or Very Low, and 8.0 or High, which again suggests that overwinter frozen stock does not perform well when planted into cool soils. Treatments Q and R and U, which were conditioned at +2 $\pm$ 1°C for six weeks before outplanting on the same dates as Treatments M and N, had OSI values of 8.0 or High and 9.5 and 9.0 or Very High, respectively suggesting that longer conditioning at +2 $\pm$ 1°C may have improved their capacity for establishment.

Examination of the RRP results measured in the Laboratory Pot Trial in 1982 with the OSI values recorded for 1983 suggests that the amount of RE and Total RN recorded during the 21-day test does not have to be large to permit establishment with acceptable OSI values (Table 2). For white spruce, RE values that ranged from 13 to >28 generally resulted in High and Very High OSI values. Treatment Q was an exception to this as it had an RE of 0 and OSI values of 8.0 or High. With the exception of Treatment Q which had a Total RN value of 1, RN values that were >29 in the 21-day RRP test resulted in OSI values in the High or Very High ranges.

Black Spruce

The $1^1/2+1^1/2$ black spruce stock had OSIs ranging from 10.0 or Very High to 5.5 or Very Low in 1983 (Table 3).

Stock Lifted in the Spring of 1982. Treatments A, B, E and G had Very High OSI values. Thus black spruce stock lifted during the first three weeks of the growing season and outplanted directly or cold stored at +2 $\pm$ 1°C for either three (Treatment E) or six (Treatment G) weeks performed very well after outplanting. Treatment C which was lifted in full flush six weeks after Treatments A and E, performed sightly less well with an OSI value of 8.0 or High.

Stock Lifted in the Fall of 1981 and Overwinter Stored at -2 $\pm$ 1°C. Treatments I and K which were planted directly from frozen storage at -2 $^+$ 1°C on May 4 and June 15 had OSI values of 8.0 or High and 7.5 or Medium respectively. The High OSI value of 8.0 for Treatment I suggests that black spruce, unlike white spruce, is able to regenerate roots and establish in the early spring in soils at approximately +5°C. Treatments M

and N which were preconditioned for three weeks at +2 $\pm$ 1°C before outplanting on May 4 and 25 had OSI values of 8.0 or High and 9.5 or Very High respectively which may indicate that there are minor advantages to both conditioning and planting black spruce stock after soil temperatures have risen approximately to the +10°C range. Treatments Q and, R and U which were conditioned at +2 $\pm$ 1°C for six weeks before outplanting on the same dates had OSI values of 8.0 or High, and 10.0 and 9.0 or Very High respectively indicating that longer preconditioning did not change their capacity for establishment.

Examination of the RRP results measured in the Laboratory Pot Trial in 1982 with the OSI values recorded for 1983 suggests that the amount of RE or Total RN recorded during the 21-day test again does not have to be large to permit establishment with acceptable OSI values (Table 3). For black spruce which has a higher RRP than the other species, RE values that were generally >49 resulted in High or Very High OSI values. Treatments I and M were exceptions to this as they had REs of 0 and 2 respectively and both had OSIs of 8.0. With the exception of these two treatments which had Total RN values of 0 and 7 respectively, RN values that were >99 in the 21-day RRP test resulted in OSI values in the High and Very High Range.

Jack Pine

The 2+0 jack pine stock had OSIs ranging from 10.0 or Very High to 1.5 or Failed in 1983 (Table 4).

Stock Lifted in the Fall of 1981 and Overwinter Stored at -2 $\pm$ 1°C. Treatments I and K which were planted directly from cold storage on May 4 and June 15 had OSI values of 6.0 and 5.0 or Low and Very Low and did not perform well. As both these treatments had 0 RE or Total RN in the Laboratory Pot Trial, it is not surprising that they performed badly at the end of the second growing season. Treatments M and N which were preconditioned for three weeks at +2 $\pm$ 1°C before outplanting on May 4 and 25 respectively had OSI values of 1.5 or Failed and 9.0 or Very High which again suggests that overwinter frozen stock does not perform well when planted into cool soils. Treatments Q and, R and U which were preconditioned at +2 $\pm$ 1°C for six weeks before outplanting on the same dates as Treatments M and N had OSI values of 4.5 or Failed, and 8.5 and 6.5 or High and Low respectively. The Failed OSI value for Treatment Q

again supports the theory that overwinter frozen stock, even preconditioned stock, does not establish effectively when outplanted into cool soils in early May.

Examination of the RRP results measured in the Laboratory Pot Trial in 1982 with the OSI values recorded for 1983 again suggests that the amount of RE or Total RN recorded in the RRP test does not have to be large to permit establishment with acceptable OSI values. For jack pine, RE values of from 13 to >35 resulted in Medium, High and Very High OSI values and RN values of from 12 to >32 resulted in a similar range of OSI values.

CONCLUSION

The summary of results and discussion in the preceeding section suggests that the evaluation of physiological quality of white and black spruce $1^1/2+1^1/2$ transplant and 2+0 jack pine seedling stock subjected to a wide range of lifting and storage treatments in 21-day laboratory tests helped to predict their percent survival and height growth at the end of the first and second growing seasons after outplanting. Outplanting Success Indices (OSIs) used to integrate percent survival and height growth results at the end of the first and second growing seasons showed which of the lifting and storage treatments were the best for each species.

The relationships between the RE and Total RN of each treatment measured in the 21-day laboratory pot trial in 1982 and the OSI values achieved by the various treatments in 1982 and 1983 in the field, showed that the RE and Total RN values measured in the pot trial did not have to be high to achieve satisfactory OSI values in the field. The Results suggest that the following approximate amounts of RE and Total RN measured in laboratory pot trials will ensure satisfactory plantation establishment and growth after outplanting.

Species	RE	Total RN
White spruce	>35	>35
Black spruce	>50	>99
Jack pine	>35	>30

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Table 1. Treatments (13) in random block design

Stock Treatment	Planting Dates (4/5)	(25/5)	(15/6)	Number of Treatments
1. SPRING LIFTED and planted 1 week after lifting.	A	B	C	3
2. SPRING LIFTED AND COLD STORED AT +2 $\pm$ 1°C on May 5 and June 2. Planted after 3 weeks in cold storage.		E	G	2
3. FALL LIFTED AND FROZEN STORED AT -2 $\pm$ 1°C in October 1980. Planted direct from frozen storage.	I		K	2
4. FALL LIFTED FROZEN STORED AT -2 $\pm$ 1°C AND CONDITIONED IN COLD STORAGE AT +2 $\pm$ 1°C for 3 weeks and 6 weeks before planting.	M Q	N R		4
5. FALL LIFTED FROZEN STORED AT -2 $\pm$ 1°C PACKED VERTICALLY IN MOSS UNDER LIGHT (ON NOV. 18) FOR ONE MONTH AND THEN FROZEN STORED OVER WINTER AS IN 4. CONDITIONED IN COLD STORAGE AT +2 $\pm$ 1°C for 3 weeks and 6 weeks before planting.		V* U		2
Total Number of Treatments	4	6	3	13

*Note: Treatment V was planted only in the greenhouse pot trial for white spruce and in the greenhouse pot trial and at the sandy outwash field site for black spruce and jack pine.

Table 2. Laboratory RRP results in 1982 vs Outplanting Success Indices for white spruce in 1982 and 1983

Treatment Details				Field Results Treatment Success Codes (TSC)				Laboratory RRP Results in 1982		Outplanting Success Index (OSI)	
				1982		1983					
Name	Lifting[1] Time	Storage Wks. at +2°C	Planting[2] Time	Survival	Height Growth	Survival	Height Growth	RE	Total RN	1982	1983
A	S	1	1	5.0	4.5	5.0	5.0	65	116	9.5	10.0
B	S	1	2	5.0	4.5	5.0	4.5	50	123	9.5	9.5
C	S	1	3	5.0	4.5	3.5	2.0	3	13	9.5	5.5
E	S	3	2	5.0	5.0	5.0	5.0	33	103	10.0	10.0
G	S	3	3	5.0	4.5	5.0	3.0	44	78	9.5	9.0
I	F	0	1	4.5	3.0	2.5	3.0	2	2	7.5	5.5
K	F	0	3	5.0	4.5	5.0	4.5	28	34	9.5	9.5
M	F	3	1	3.5	2.5	2.5	3.0	0	0	6.0	5.5
N	F	3	2	5.0	4.5	4.5	3.5	51	61	9.5	8.0
Q	F	6	1	4.0	3.0	4.0	4.0	1	1	7.0	8.0
R	F	6	2	5.0	4.5	5.0	4.5	39	65	9.5	9.5
U	F	6	2	5.0	4.5	5.0	4.0	13	29	9.5	9.0

Notes: [1]Lifting Times, S = spring, F = fall. [2]Planting Times, 1 = May 4, 2 = May 25 and 3 = June 15, 1982.

Table 3. Laboratory RRP results in 1982 vs Outplanting Success Indices for black spruce in 1982 and 1983

Treatment Details				Field Results Treatment Success Codes (TSC)				Laboratory RRP Results in 1982		Outplanting Success Index (OSI)	
				1982		1983					
Name	Lifting[1] Time	Storage Wks. at +2°C	Planting[2] Time	Survival	Height Growth	Survival	Height Growth	RE cm	Total RN	1982	1983
A	S	1	1	5.0	5.0.	5.0	5.0	143	187	10.0	10.0
B	S	1		5.0	5.0	5.0	5.0	126	197	10.0	10.0
C	S	1	3	5.0	4.0	5.0	3.0	181	194	9.0	8.0
E	S	3	2	5.0	4.5	5.0	5.0	116	193	9.5	10.0
G	S	3	3	5.0	4.5	5.0	4.5	96	148	9.5	9.5
I	F	0	1	4.5	3.0	4.5	3.5	0	0	7.5	8.0
K	F	0	3	4.5	3.5	4.5	3.0	19	31	8.0	9.5
M	F	3	1	4.0	3.5	4.0	4.0	2	7	7.5	8.0
N	F	3	2	5.0	5.0	5.0	4.5	354	224	10.0	9.5
Q	F	6	1	4.0	2.5	4.0	4.0	49	99	6.5	8.0
R	F	6	2	5.0	5.0	5.0	5.0	195	206	10.0	10.0
U	F	6	2	5.0	4.0	4.5	4.5	61	109	9.0	9.0

Notes: [1]Lifting Times, S = spring, F = fall. [2]Planting Times, 1 = May 4, 2 = May 25 and 3 = June 15, 1982.

Table 4. Laboratory RRP results in 1982 vs Outplanting Success Indices for jack pine in 1982 and 1983

Treatment Details				Field Results Treatment Success Codes (TSC)				Laboratory RRP Results in 1982		Outplanting Success Index (OSI)	
				1982		1983					
Name	Lifting[1] Time	Storage Wks. at +2°C	Planting[2] Time	Survival	Height Growth	Survival	Height Growth	RE cm	Total RN	1982	1983
A	S	1	1	5.0	5.0	5.0	5.0	231	152	10.0	10.0
B	S	1	2	5.0	3.0	4.5	5.0	13	35	8.0	9.5
C	S	1	3	5.0	5.0	4.5	3.0	3	12	10.0	7.5
E	S	3	2	5.0	3.5	5.0	4.5	87	108	8.5	9.5
G	S	3	3	4.5	2.5	4.0	3.5	34	32	7.0	7.5
I	F	0	1	2.5	2.0	2.5	3.5	0	0	4.5	6.0
K	F	0	3	3.5	1.0	2.0	3.0	0	0	4.5	5.0
M	F	3	1	0.5	0.0	0.5	1.0	0	0	0.5	1.5
N	F	3	2	4.5	3.5	4.0	5.0	64	64	8.0	9.0
Q	F	6	1	2.5	2.0	2.0	2.5	0	0	4.5	4.5
R	F	6	2	4.0	2.5	3.5	5.0	36	33	6.5	8.5
U	F	6	2	4.0	2.5	3.5	3.0	3	12	6.5	6.5

Notes: [1]Lifting Times, S = spring, F = fall. [2]Planting Times, 1 = May 4, 2 = May 25 and 3 = June 15, 1982.

COMPUTER COMMITTEE REPORT

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The past year has seen a growing number of Nurseries become equipped with Dec Professional 350 micro-computers. At present, only Dryden and Midhurst of the seven large nurseries and the Stock Production Unit of Main Office have yet to acquire their own machines.

At the last two meetings of Nursery Superintendents, a list of required computer programs was outlined and partly priorized. The tree order program has been operational at Kemptville this past season. This program should shortly be ready for installation on the the southern nursery computers, and should probably be applicable for the northern bare root nurseries.

The second program to be developed is a comprehensive program to prepare the general and detailed work plans, compare the expenditures with the calendarization, complete payroll functions, and prepare the annual cost report.

Glenn McLeod was to prepare a detailed outline of requirements, but due to the passing of John Breen in late winter, has had his hands full with more routine matters. From conversations between Glenn and Dolf, and two meetings between Nancy Brown from Midhurst and Arlene Ruttan from Swastika, the following brief outline has developed to date:

1) The system should generally include the work plans, expenditure control, payrolling, and annual cost report.
2) Include the nursery cost codes by Salaries "A" and "B" and Other.

3) Charges could be entered daily or monthly, and should include confirmed MIS charges, plus accruals from purchase orders and salaries.
4) Payrolling would include setting up bi-weekly time sheets by employees, calculating the time sheets, preparing payroll summaries and calculating Unemployment Insurance Termination forms. At Swastika Nursery, the computer is programmed so when the time is entered by code from the daily time cards, you are able to acquire 4 reports: 1. your daily cost by code, 2. the Bi-weekly payroll expenditure, 3. the month end cost, and 4. your year-to-date cost by code. You can also get a total by Activity.
5) Making monthly and quarterly cost reports comparing actual expenditures with calendarization of the work plan. This could be done by code or by grouping of codes, (i.e. Seeding, Tending, Transplanting, Shipping, Overhead, etc.).
6) Preparing the annual nursery cost report.
7) The general work plans for January and October should be included as well as the March detailed work plan.

This description of the system will be sent to each of you for comments, and will be then revised and sent to Forest Resources to request financing for the programming. Similar to the Kemptville program, a small committee could be established to review and comment on progress during this programming.

Just to bring you up to date on the uses of the DEC's to date, I am aware of the following:

- Using Supercomp, St. Williams and Midhurst have prepared their detailed work plans.
- Using Supercomp, Midhurst is comparing actual expenditures with calendarization by groups of codes.
- Using Supercomp, St. Williams is summarizing payroll codes.
- The most significant move is at Swastika, where a programmer has been hired for 9 months to use Datatrieve to enter each time card daily by codes to summarize costs for each bi-weekly payroll date. The next step is to enter the daily costs by employee.

- Wingham District has the "B" Salary payroll on DEC. Glenn has requested a copy of the program, and will forward it to each Nursery.
- Maple District is in the early stages on programming the DEC for the annual equipment inventory.

None of these developments are comprehensive enough to satisfy our general requirements, but they may contribute to the final package.

Are there any other uses of the Micros?

ACCELERATED TRANSPLANTS

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When originally asked to speak on this topic by the organizers of this conference, I was to cover our observations and accomplishments of our trip to California, as well as a report on the status of an operational scale trial with miniplugs of rubber soil carried out at Thunder Bay. I will be getting to those topics shortly, but first I thought it would be appropriate to give a little background on accelerated transplants and why we are considering such production methods.

My interest in accelerated transplants was ignited shortly after my arrival at Kemptville back in 1977. At that time Alf Campbell, Roy Fitzgerald, Gerry Wright and others at that nursery, were expressing how advantageous it would be to get more control over the very early stages of seedling growth. About the same time a larch program was gaining momentum and the nursery was expected to grow a lot of larch from very small quantities of valuable seed. In investigating a solution to these problems, I learned that Doug Skeates was already investigating this with Dewa Blocks, John Scarratt with paperpots and Clave Mahonen with bareroot seedlings in a Finn house. So you can see that the accelerated transplant idea is not a new one. It is my understanding that since then all of the Provincial nurseries have had some involvement in accelerated transplants.

Why accelerated transplants -

Since assuming duties at the Thunder Bay Forest Nursery I am convinced more than ever of the need for accelerated transplants. I will itemize and expand upon some of these needs:-

1. Land requirements: With expanding production targets, it is becoming ever more important to optimize the use of the nursery land base. By producing seedling stage trees at dense spacing in a greenhouse, compartments previously used as seed beds can now be used for transplants.

2. Reliability: With the increasing demand for nursery stock and the very high costs of site preparation it is no longer tolerable to fall far short of production targets because of the kind of disasters to which the seedling stage is vulnerable.

3. Seed utilization: Not only is it becoming more costly to collect and process cones, the availability of which has kept us guessing in recent years, but the development and maintenance of seed production areas, seed collection areas and other tree improvement efforts have contributed to the high value of the seed. Under traditional production techniques it is often necessary to sow 10 - 12 seeds for every tree shipped to overcome such unpredictable and uncontrollable operations and other factors such as: sowing dates, seed placement, mulching, erosion, fungi damping off, birds, rodents, irrigation, weeds, machinery damage, weed extraction damage, exposure, frost damage and frost heaving.

Though no control is possible over some of the factors mentioned above, elaborate and very expensive procedures and measures have been developed in attempting to overcome the effects of others. Some of these procedures and measures include: seed treating and coating to combat the effects of fungi, birds, rodents; mulching to combat erosion, pre-emergent chemicals for weeds, specialized row crop equipment to minimize machinery damage, and probably the most costly - shading, to reduce the effects of sun scald, wind burn, dehydration, frost damage and frost heaving.

I will now proceed with a slide presentation of the Castle and Cooke operation in California, a bit of a travelogue on California attractions and our production trial with white spruce and black spruce in "rubber soil" at the Thunder Bay Forest Nursery.

QUALITY CONTROL IN TREE PLANTING AND ITS EFFECT ON SURVIVAL

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Kirkland Lake District has been monitoring planting quality formally since 1979. With the advent of large scale contracting (three [3] million trees in 1984) the process became the basis for payment to the contractors.

Data is summarized to determine the planting quality for payment and the most common planting faults.

A supplementary assessment is done to relate the planting attribute to the health of the trees.

Assessment Method

Ten metre square plots are established randomly throughout the planting area. The sample area is 100 square metres (0.010 hectares) and the sampling intensity is 0.2%.

Each plot is assessed for the number of plantable spots, number of trees planted and the number of trees planted unsatisfactorily as soon as possible after planting. The unsatisfactory attributes are as follows:

1. Unsuitable Microsite
2. Firmness
3. Tree Root Placement (root position)
4. Planting Depth (deep, shallow, multiples)
5. Stem and Crown Position (leaning trees)
6. Scalping (spot not scalped)

These attributes are taken from the 1984 Northern Region Planting Agreement.

The supplementary assessments are completed on the same tally sheet in the fall after outplanting.

Survival is checked and listed as dead, healthy, unhealthy, or missing. The height in centimetres is completed as well to indicate growth.

Figure 1 is the tally sheet used.

Planting Quality Results

Table 1 summarizes the attributes as they were assessed in 1982 and 1983 for bareroot stock.

Table 1. Bareroot Planting Quality in 1982 and 1983 in the Kirkland Lake District

Planting Quality	1982		1983	
	# Trees	%	# Trees	%
Total Trees Assessed	3739	100	5928	100
Total Satisfactory	2942	79	5033	85
Total Unsatisfactory	797	21	895	15
Unsuitable Microsite	52	6	90	10
Firmness	386	48	279	31
Tree Root Placement	121	15	268	30
Planting Depth	134	17	178	21
Stem & Crown Position	88	11	46	5
Multiples Per Hole	11	2	22	2
Tree Condition	5	1	12	1

The overall planting quality is increasing. This is to be expected as contractors are being paid on their quality and the Crown crews have become more knowledgeable on the requirements for correct planting. The formalized assessment allows everyone to relate how each crew is doing.

The most common faults have remained the same. They are: lack of firmness, poor root placement, and incorrect planting depth.

Survival Results Related to Planting Quality Attributes

These plots have been assessed for survival to satisfy the regeneration assessment manual and these results were then correlated with the planting quality attributes.

Table 2 outlines the relationships between the spring quality assessment and fall supplementary assessment for 1982.

Of the satisfactorily planted trees nine percent died and nineteen percent appeared to be unhealthy. The unsatisfactorily planted trees were twenty-two percent unhealthy and twenty-one percent dead.

These figures are similar to those found by Thompson (1979).

The attributes that have the most effect on survival are unsuitable microsite and improper firmness. This was expected. Growth measurements are the next requirement to be related to planting quality.

Discussion

These results indicate the attributes that we, as field people, must be aware of. The ten percent of the stock that dies, even though it was well planted, may be where the nurserymen can help to improve the success rate.

The areas I feel we should concentrate on are as follows:

1. Field storage and handling (field problem)
2. Handling practices while lifting and grading (nursery problem)
3. Tree condition at time of lifting (nursery problem)

With the research work going on at present in these areas and with some real care by all of us involved, I'm sure we can reduce the mortality of well-planted trees.

Reference

Anon. 1984. Northern Region Planting Agreement. Ontario Ministry of Natural Resources.

Thompson, J.R. 1979. Planting Quality Assessment in the North Central Region. Ontario Ministry of Natural Resources.

Table 2. Supplementary Assessment 1982, Kirkland Lake District (Nursery Stock)

PLANTING QUALITY	HEALTHY		UNHEALTHY		DEAD		MISSING		TOTALS
	# of Trees	%	# of Trees	%	# of Trees	%	# of Trees	%	
Satisfactory	2 129	72	543	19	265	9	5		2 942
Unsuitable Microsite	25	48	13	25	14	27	-		52
Firmness	179	46	87	23	119	31	1		386
Tree Root Placement	85	70	21	17	15	13	-		121
Deep	102	76	25	19	6	4	1	1	134
Leaning Stem Position	57	65	19	21	12	14	-		88
Double Planting	6	55	3	27	2	18	-		11
Tree Condition	3	60	0	0	2	40	-		5
Total Unsatisfactory	457	57	168	21	170	21	7	1	797
Total									3 739

Sample of 3 739 trees planted 1982

Quality Assessment — Spring 1982

Supplementary Assessment -- Fall 1982

Planting Quality - 79%

PLANTING QUALITY AND SURVIVAL ASSESSMENT

District: Kirkland Lake Township: _____ Project No: _____

Date: _____ Plot No: _____ Planting Stock: _____ Planting Crew: ___

Survival Assessment Assessors: _____

No	Planting Quality: S	D	1	2	3	4	5	6	7	8	Supplement Assess: D	H	U	M	HT cm	1st Year Assess: D	H	U	M	HT cm	2nd Year Assess: D	H	U	M	HT cm

COMMENTS:

Planting Quality:

% Satis Planted	Survival % S	1	2	Height-cms S	1	2
	(1)	(2)		(3)		(4)

Planted trees on Plot	Trees/ Hectare (1)x100	Natural Accept. Conifer	Total (1)+(3) trees/ha x100

Survival:

FIGURE 1.

Survival Codes

D - Dead
H - Healthy
U - Unhealthy
M - Missing

Planting Quality Codes

S - Satisfactory
D - Dead
1 - Unsuitable Microsite
2 - Firmness
3 - Tree Root Placement
4 - Deep Planting (D) Shallow (S) Multiple Trees (M)
5 - Stem & Crown Position
6 - Scalping
7 - Density
8 - Spacing

Figure 1. Planting quality and survival assessment tally sheet.

PATHLESS NURSERY COMPARTMENTS

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The idea of Pathless Compartments, I think, is impossible; but the Semi-Pathless Compartment is very much a reality. The following diagrams and tables show you how it can be set up, and what the gains are.

We approached the subject with strictly the idea in mind of looking at the feasibility and making this report the first step to let people know what could be gained if they considered going to this sort of system. It is really an information package that will have a slightly different approach for each Nursery.

Significant gains can be made as seen from the table. We estimate around 30% more trees per hectare or 202 M trees/ha. We considered the whole study for strictly transplant beds, not seedbeds.

The problems are generally minor except for the lifting where one would, it seems, have to go to a Mechanical Harvester that is self-propelled. The hand weeding is made more difficult as some areas will be a little more inaccessible with the lack of paths. In our case, we find that hand weeding in transplant beds is minimal anyway. Bed inspection also is hampered by lack of paths. In the case of fertilizer, the injection through an irrigation system would be ideal. If boom sprayers or bog-bales are used, some slight equipment changes may need to be made. For example a boom sprayer would have to be able to spray 5 bed widths with one pass.

In conclusion, I think with the increasing targets and decreasing growing areas, semi-pathless compartments are something that we will have to consider soon. It might very well be worth an initial investment to have a consultant firm make a professional study of the gains -- a decision that will have to be made at the head office level.

Table 1. "Semi-Pathless" study

	PRESENT SYSTEM	PROPOSED SYSTEM
Gross Area	2,377 m^2 (0.2377 ha)	2,377 m^2 (0.2377 ha)
Path Area	914 m^2 (0.0914 ha0	503 m^2 (0.053 ha)
Bed Area	1463 m^2 (0.1463 ha)	1874 m^2 (0.1874 ha)
Rows of Trees/Section	64	84
Total Trees Per Section	157,440	206,640
Total Trees Per Hectare	662,347	869,331
% of Production	100%	131%
Difference Per Hectare	N/A	31% 206,984 trees

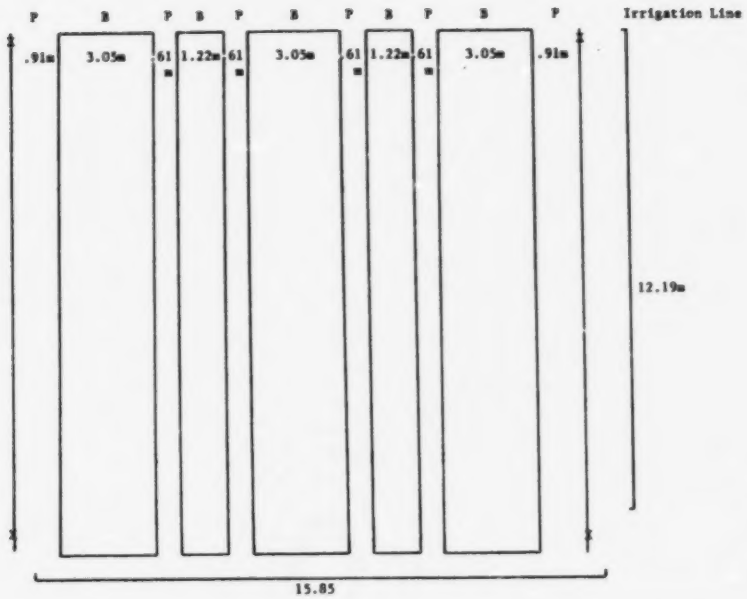

Figure 1. Old 8 bed compartments section gone semi-pathless.

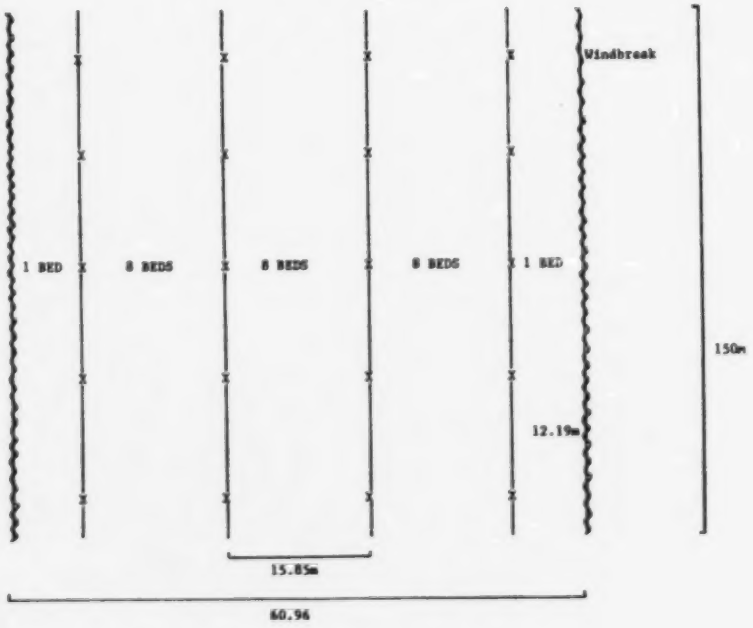

Figure 2. Typical compartment set-up at Dryden Tree Nursery.

NUTRITIONAL EFFECTS OF PAPERS USED FOR FH 408 CONTAINERS

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We investigated problems of container paper quality after receiving complaints from a Thunder Bay commercial grower about inferior performance of seedlings grown in containers of Finnish manufacture. Compared to Japanese made papers, the Finnish papers produced smaller trees and required more intensive fertilization. We suspected that the Finnish paper caused greater immobilization of N in the growing media, and obtained samples to test for this. Our initial efforts were directed at 1) duplicating the growth deficiencies experimentally, and 2) examining effects of the paper types on the N status of the peat used as the growing media.

The two types of paperpots were fitted into 2 standard paperpot trays as sections of 30 cavities each forming 6 randomly located replications of 20 seedlings (the border trees acted as buffers and were not sampled). The containers were filled by hand with moist peat/vermiculite (3:1) growing media and were seeded with jack pine. A nutrient regime using Plan Products 20-20-20 fertilizer as a continuous feed was started one month after germination. Differences in growth and development were noticeable within 6 weeks after germination, and continued until harvest (at 12 weeks) as shown in Table 1. Seedlings reared in Finnish paper were much smaller in dry matter and height development, thus confirming the observations noted by the commercial grower.

Tests were set up to observe the reaction between the papers and peat under controlled incubation conditions. An equivalent amount of peat used to fill one FH 408 paperpot cavity was mixed with a single ground paper of Japanese or Finnish manufacture. The sample was placed in a glass jar, brought to moisture content of greenhouse growing conditions, and incubated aerobically for one week at 30°C. Mineralizable N recovered from the paper/peat mixtures after incubation indicated that a greater amount of N was immobilized by the Finnish paper as compared to the Japanese paper (Table 2), providing evidence that the growth decline of the seedlings was probably due to a deficiency of nitrogen.

The next step was to determine if increased amounts of nutrient solution could offset the immobilizing properties of the paper, both under incubation and under greenhouse conditions. A pot trial was set up placing individual paperpots of different manufacture into 15 cm plastic pots and treating each with one of 5 rates of nutrient solution (Plant Products 20-20-20 fertilizer at 0, 120, 180, 240, and 300 ppm N). At the same time incubation experiments were conducted with peat/paper samples that were treated with similar rates of solution used in the greenhouse trial. Controls of identical samples without the added paper were included. Figure 1 illustrates the recovery of mineral N from the incubated samples relative to the corresponding controls. Added fertilizer promoted net N mineralization of the Japanese paper mix which dropped off at high additions probably because of salt toxicity to microorganism. Fertilization of the Finnish paper mix reduced immobilization of N proportionally with increasing rates, but failed to induce net mineralization. These results provided further evidence of reduced N availability in peat mixed with the Finnish papers.

The seedlings from the pot trial showed parallel trends in terms of growth development (Table 3) and N uptake (Figure 2). Although dry weight of seedlings grown in the Finnish containers increased with higher nutrient levels, they failed to match the size of Japanese containers. Growth of the latter reflected typical patterns of deficiency, sufficiency, and toxicity with increasing nutrient levels. The seedlings grown in Finnish papers appeared more responsive to higher fertilization since they lacked toxicity symptoms. The trends of seedling N uptake (Figure 2) correlated well with N

recovery data of the peat incubations (Figure 3), and illustrate the potential of short term incubation methods for predicting future growth responses of seedlings.

To check consistency between paper lots we repeated this experiment on a larger scale with newer Finnish and Japanese paperpots supplied by Hakmet Ltd., the Canadian distributor of these containers. This time we employed a more soluble nutrient solution applied at higher concentrations than the previous trial. The paperpots were placed in "mini" trays which held 16 containers of each type. Treatments were replicated (3x), and consisted of a complete "Glendon Hall" nutrient solution applied at 5, 22, 112, 560 and 784 ppm N as constant feed. At 6 weeks, the seedlings exhibited the expected response to fertilizer levels, but surprisingly no growth difference between paper types was evident. Subsequent incubation tests with the newer papers revealed only small differences in N mineralization between the two peat/paper mixes. These results indicated that the newly acquired paper sets were of equivalent quality in terms of N status. We repeated the experiment using the older Thunder Bay papers, and again detected differences in seedling growth performance (Table 4). However, despite higher rates of fertilization additions, seedling performance of the Finnish containers did not match that of the Japanese containers. Apparently, nutrients other than N became toxic at these high levels of complete fertilizer solution.

Analysis of organic carbon and total nitrogen of the 4 paper types revealed that the C/N ratio of the Finnish paper from the Thunder Bay grower was nearly twice as high as that of the others (Table 5). The higher value of the former would explain enhanced microbial immobilization of N in the growing media, which would in turn reduce N availability in the rooting zone, leading to N deficiency in the seedlings. It is reassuring to report that the newer Finnish paperpots supplied by the distributor performed on a par with the Japanese papers. Based on these experiences, we recommend that as a precautionary measure before use, papers suspected of causing growth inhibition in crops be evaluated by chemical analysis or appropriate incubation techniques.

Table 1. Height and weight of 12-wk old jack pine seedlings grown in containers of Japanese and Finnish manufacture (mean of 6 replications each consisting of 20 seedlings).

Paper	Height	Dry Weight
	cm	g
Japanese	12.9	.29
Finnish	11.5	.20
Difference	*	**

*, ** significant at .05 and .01 levels, respectively.

Table 2. Mineral (NH_4+NO_3) N in peat/paper samples before and after 1-week of incubation at 30°C.

Paper	Mineral - N (ppm)	
	Before	After
Control (no paper)	19	21.5
Japanese	21	28.3
Finnish	18	0.5

Table 3. Dry weight (g) of 12-week old jack pine seedlings raised at varying fertility levels in Japanese and Finnish containers grown in flower pots (mean of 3 seedlings).

Paper	Concentration of nutrient solutions[1]				
	0	120	180	240	300
Japanese	.14	.33	.30	.26	.21
Finnish	.06	.16	.17	.17	.20

[1] ppm N as Plant Products 20-20-20 fertilizer.

Table 4. Dry weight (g) of 12-week old jack pine seedlings raised at varying (and higher) fertility levels in Japanese and Finnish paperpots (mean of 3 replications, each comprised of 16 seedlings).

	Concentration of nutrient solution[1]				
Paper	5	22	112	560	784
Japanese	.09	.16	.30	.21	.18
Finnish	.04	.12	.20	.16	.13
Difference	*	*	**	*	*

*, ** significant at 0.05 and 0.01 level, respectively.

[1] ppm N as complete "Glendon Hall" solution.

Table 5. Carbon/Nitrogen ratio of Japanese and Finnish papers supplied by the Thunder Bay grower and by Hakmet, Ltd.

Paper type	Organic C(%)	Total N(%)	C/N
Thunder Bay (old)			
Japanese	57	.72	79
Finnish	57	.36	159
Hakmet (new)			
Japanese	57	.80	72
Finnish	57	.70	81

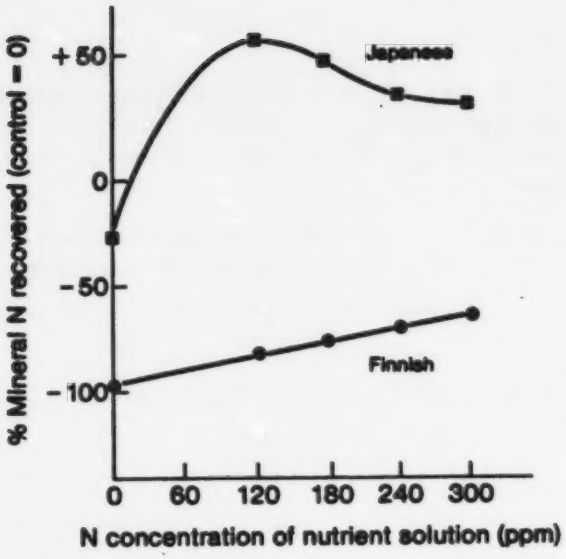

Figure 1. Recovery of mineral N ($NH_4^+NO_3^-$) from peat/paper mix relative to controls after 1-wk incubation. Controls had no paper added; nutrient solutions were applied at start of incubation.

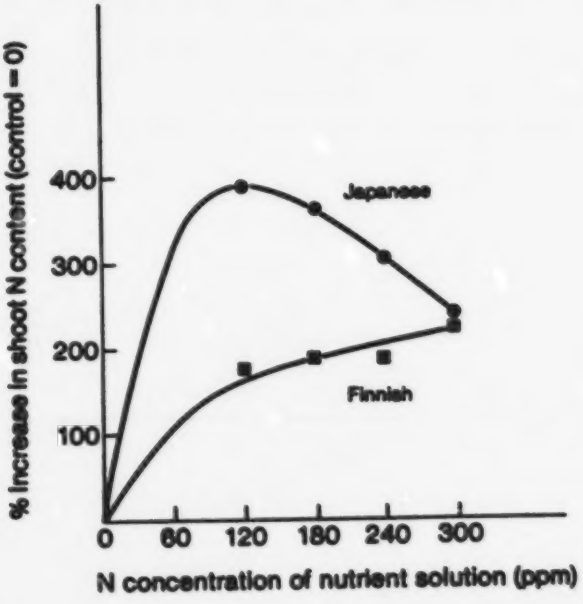

Figure 2. Shoot N status of jack pine seedlings relative to the control (water only treatment). Seedlings were grown in paper containers of Japanese and Finnish manufacture.

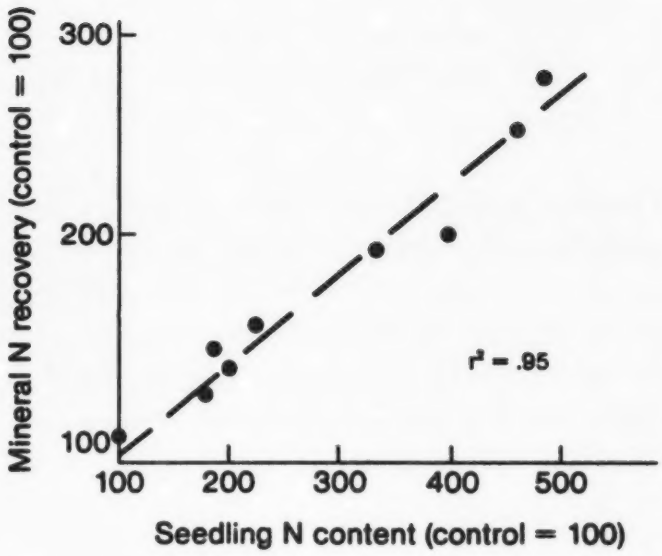

Figure 3. Relationship between mineral N recovered from incubated peat/paper mix and N content of seedlings treated with equivalent rates of nutrient solution. Values are relative to controls which have been equalized to 100.

FOREST FLOOR EFFECTS ON GROWTH OF BLACK SPRUCE CONTAINER SEEDLINGS

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A preliminary experiment conducted at Glendon Hall over the winter of 1983 found marked differences in growth of black spruce seedlings planted on forest floors from 2 different site types in the northern Clay Belt. The short term trial is part of a larger study that will look at seedling responses in relation to forest floor nutrient status over a range of site conditions. The sites are defined as operational groups (OG) of the Forest Ecosystem Classification system (Jones et al., 1983).

Intact blocks of sphagnum and feather moss forest floors were collected from two contrasting black spruce site types that cover significant areas in the Clay Belt: a lowland Labrador tea site, OG 11 (Ledum), and an upland feather moss site, OG 4 (Feather moss - Coarse soil). Black spruce containerized seedlings produced at Swastika nursery were washed free from the growing media and were planted as bareroot stock in large rectangular plastic tubs containing the forest floor (12 trees/ block). The seedlings were grown for 5 months in the greenhouse under natural day length, supplemented to 18 hours with high intensity lights. The trees were not fertilized, but were irrigated as needed.

After 4 months, response differences were noted in both height and colour of seedlings. Height increments of seedlings on sphagnum decreased considerably in the 4th and 5th month (Figure 1). Foliage was distinctly chlorotic and new growth was less vigorous. Seedlings on the feather moss treatment continued to respond with relatively larger height increments and new growth was vigorous and exhibited normal colouring. Morphological differences in seedlings at harvest (5 months) are noted in Table 1.

The moisture regime of the two substrates was monitored by soil tensiometers. Readings indicated only small differences in moisture availability of the rooting zones. Chemical analysis of the harvested seedlings suggested that deficiency in N may have caused growth differences since N concentration of trees planted on sphagnum was much lower than those on feather moss. Status of all nutrients were compared on a relative basis by plotting shoot nutrient concentration against absolute content (concentration x dry weight), with levels of sphagnum adjusted to 100 (Figure 2). The diagonal lines represent increments of dry weight. Figure 2 shows that differences were largest for N. Diagnostic interpretations based on direction of each vector (arrow) in Figure 2, suggest that N is the major nutrient limiting growth (Timmer and Stone 1978).

Comparisons of seedling N status at the start and end of the growth trial also support these observations (Table 2). Over the 5 months period N concentrations in the trees decreased considerably, but the decline was less for seedlings planted on the feather moss. The seedlings on the sphagnum did not gain any N in their tissues, consequently the reserves of N were diluted. In contrast, N content on the feather moss increased considerably, suggesting that N was more available on this substrate. The apparent N deficiency on the sphagnum peat will be looked at in more detail in future studies.

Another objective of our study is to look at the possibility of manipulating the fertilizer regime of container stock to produce seedlings with high N reserves that would respond better on nutrient stressed sites. We illustrate this approach with data from a supplementary experiment.

Seedlings (red pine) were grown from seed under a range of fertilizer regimes over a 15-week period. At the end of this period, tissue analysis was carried out to compare plant nutrient uptake under the different regimes. Table 3 shows dry weight and N uptake of seedlings grown at 1/4 (1/4 R), 1 (R) and 4 (4R) times the recommended rate of application, and an additional treatment of extra N (XN). Although there were only small differences in height growth and dry weight between treatments, marked differences in N uptake were noted. The 1/4 R treatment produced heavier seedlings than the R treatment despite lower N levels. Solutions of high N concentration induced luxury consumption; thus more N was taken up by the

trees but this did not result in extra growth. This excess, however, may represent an accumulated reserve of N for future growth. We intend to test the possibility of deliberately growing container seedlings at a high N regime for outplanting on specific sites, such as OG 11, which appear to be N deficient. The higher reserves of N in the tissues may improve the initial establishment of the seedlings.

In summary, N deficiency appears to be the main factor responsible for observed differences in early growth of seedlings on the two forest floors. Reasons for decreased N uptake on the sphagnum peat will be examined in more detail using techniques which will include chemical analyses and incubation experiments. Fertilization field trials will also be conducted to assess seedling responses to N fertilization on different forest floors. We hope this will contribute to the knowledge of producing more site-specific planting stock for reforestation purposes.

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Jones, R.K., G. Pierpoint, G.M. Wickware, J.K. Jeglum, R. Arnup and J. Bowles. 1983. Forest Ecosystem Classification. Ontario Ministry of Natural Resources, Toronto. 1983.

Timmer, V.R. and E.L. Stone. 1978. Growth response of young balsam fir fertilized with nitrogen, phosphorus, potassium and lime. Soil Sci. Soc. Am. J. 42: 125-130.

Table 1. Morphological characteristics of black spruce seedlings grown on sphagnum and feather moss[1].

Forest Floor	Height (cm)	Diameter (mm)	RAI (cm^2)	Shoot dry weight (g)
Sphagnum	31.3	3.06	26.0	1.68
Feather moss	41.8	3.60	27.8	2.87

[1]Data based on 2 replications of 12 trees each.

Table 2. Shoot dry weight and N levels of black spruce seedlings before and 6 months after planting on forest floor dominated by sphagnum or feather moss[1].

Sample	Shoot dry weight (g)	N Concentration (%)	N Content (mg/seedling)
Before planting	.48	2.48	11.9
Planted on sphagnum	1.68	.69	11.6
Planted on feather moss	2.88	.99	28.5

[1]Data based on 2 replications of 4 trees each.

Table 3. Dry weight and N content of 14-week old red pine container seedlings subject to four fertilizer regimes.[1]

Fertilizer regime[2]	Seedling dry weight (g)	N Uptake (mg/seedling)
1/4R	134	2.73
R	130	3.32
4/R	129	2.74
XN	143	3.62

[1]Data based on 3 replications of 18 trees each.
[2]R = 100 ppm N of Plant Products 20-8-20 fertilizer.
XN = R + 300 ppm N (as NH_4NO_3).

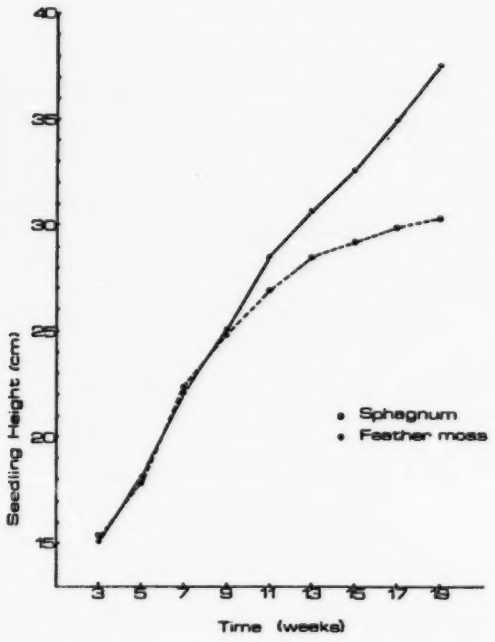

Figure 1. Height growth of black spruce seedlings planted on intact sphagnum or feather moss substrates in the greenhouse.

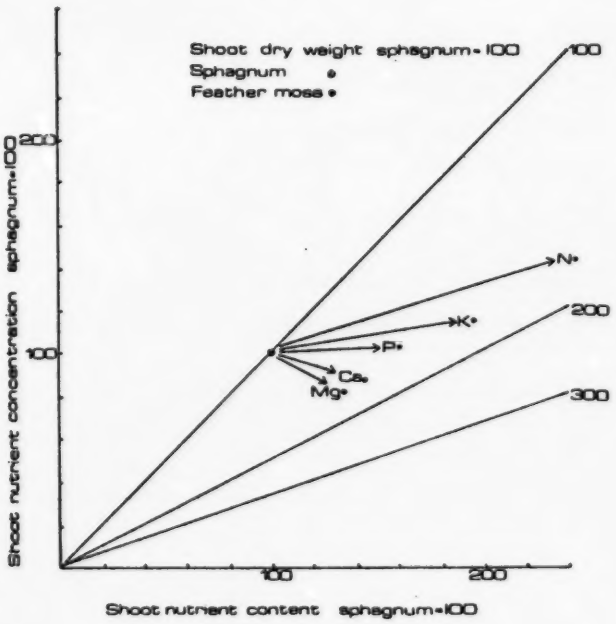

Figure 2. Relative nutrient composition and dry weight of seedling tops grown on sphagnum or feather moss (levels for sphagnum are equalized to 100). Arrow length reflect differences in nutrient status between samples.

TESTING ANTITRANSPIRANTS FOR NURSERY USE

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L0J 1E0

Introduction

When a tree seedling loses water through transpiration at a greater rate than it can be replenished from the soil, moisture stresses will occur. Any procedure by which nurserymen can reduce damaging water loss from seedlings should be investigated.

One procedure, used operationally for some agricultural crops, is the application of film-forming antitranspirants. These are liquid preparations of wax-like polymers that form a thin layer over plant surfaces when applied. This water resistant film is intended to lessen transpiration by forming a physical barrier to moisture loss.

Most antitranspirant manufacturers recommend their products for a range of species, including conifers, especially for transplants and for winter damage protection. Differences may exist, however, between a manufacturer's claims for his product and actual field performance. Prior to any product being used in the field, laboratory testing should first be carried out to distinguish the products which are most effective and to ensure that damaging side-effects do not occur.

In order to test the six antitranspirants that become available to us two efficacy tests and several other related trials were conducted.

Laboratory Testing

Black spruce container seedlings with their root plugs sealed in plastic bags were dip-treated with the various antitranspirant solutions and were

left unwatered, in the laboratory, to dry by transpiration. Periodic weight measurements of the seedlings were recorded and water loss was expressed as a cumulative percent of the total water content. In theory, the more effective the antitranspirant, the slower the rate of water loss from the seedlings.

In the first test (Figure 1), Plantco antidesiccant[1] and Cloudcover[2] were applied at their recommended rates and an experimental product X2-1337[3] was applied at a rate found to be effective in other experiments (Davies and Kozlowski 1974).

Plantco antidesiccant and Cloudcover did significantly reduce water loss in the first few days of drying, but by day 15 there were no differences between these treatments and the control. Seedlings treated with X2-1337 did show a significant reduction in water loss throughout the trial. There were no symptoms of toxicity from these three antitranspirants and further testing is planned.

In the second test, Clearspray[4], Folicote[5] and Vapor Gard[6] were applied at their recommended rates (Figure 2). In addition, Folicote was applied at four times its recommended rate. Both Folicote at the two concentrations and Clearspray were ineffective at decreasing water loss. Vapor Gard dramatically reduced transpiration and by the end of the 28 day trial, seedlings treated with Vapor Gard had lost only 22% of their total water content, whereas the control seedlings had lost 92%. The effectiveness of Vapor Gard was not without cost, however, and by the end of the trial, 80% of the treated seedlings were showing symptoms of toxicity. This was apparent as browning of the needles, usually on the tips of the main stems. In the more severe cases, terminal buds were found to be dead.

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1 Plant Products Co. Ltd., 314 Orenda Rd., Bramalea, Ont. L6T 1G1

2 Adkar Inc., 1006 S. Tenth, McAllen, TX. 78501

3 Dow-Corning Canada Inc., 6747 Campobella Rd., Mississauga, Ont. L5N 2M1

4 Miller Chemical and Fertilizer Corp., P.O. Box 333, Radio Rd., Hanover, PA. 17331

5 W.A. Cleary Chemical Corp., P.O. Box 10, 1049 Somerset St., Somerset, NJ. 08873

6 Sunoco Inc., 25 Overlea Blvd., Bldg. #1, Toronto, Ont. M4H 1B5

Another undesirable side-effect that occurred after Vapor Gard treatment was poor bud flush, evident as reduced shoot elongation accompanied by stunted needle growth. This latter damage could be due to either the toxicity previously described or to a mechanical impediment from the sticky antitranspirant residue remaining on the bud.

Further tests are now in progress to establish if lower application rates of Vapor Gard can avoid toxicity while still remaining effective. One way in which the effectiveness of lower concentrations of Vapor Gard may be enhanced is through the use of surfactants, substances that allow spray materials to spread more evenly over plant surfaces. To test this hypothesis, Vapor Gard was applied at the recommended rate of 5% and also at a rate of only 1%. The 1% rate was applied in combination with three surfactants, Tween 20, Atplus 401 and Canplus 300. Each surfactant was applied at two rates, 0.15% and 0.50%. After sixteen days of drying, water loss, as percent total water content, was determined (Figure 3). Vapor Gard applied at 1% was ineffective at reducing water loss and none of the surfactant treatments were able to increase its effectiveness. There were no symptoms of toxicity due to Vapor Gard used at the 1% rate.

Field Testing

Once laboratory trials have identified promising products to be tested further, field studies should be conducted.

A trial was established at Midhurst Tree Nursery to determine if antitranspirants could reduce damage due to winter drying. Antitranspirants were sprayed on the shoots of 3+0 black spruce seedlings in November 1983. Winter conditions in 1983-1984 did not result in winter drying damage at Midhurst. The effect of antitranspirants on outplanting performance of seedlings is also being tested and treated trees have been outplanted at the Midhurst Research Station where they are being monitored for survival, damage, shoot growth, root growth capacity and plant moisture stress. Preliminary results show improvements in rates of flushing and plant moisture stress in response to some antitranspirant treatments.

Conclusion

Because some of the antitranspirants tested have been proven effective in reducing water loss from tree seedlings, these products may be useful under some nursery and field situations. Thorough testing, however, must be continued to determine safe yet effective rates of antitranspirant application.

Reference

Davies, W.J. and T. Kozlowski. 1975. Effect of applied abscisic acid and silicone on water relations and photosynthesis of woody plants. Can. J. For. Res. 5: 90-96.

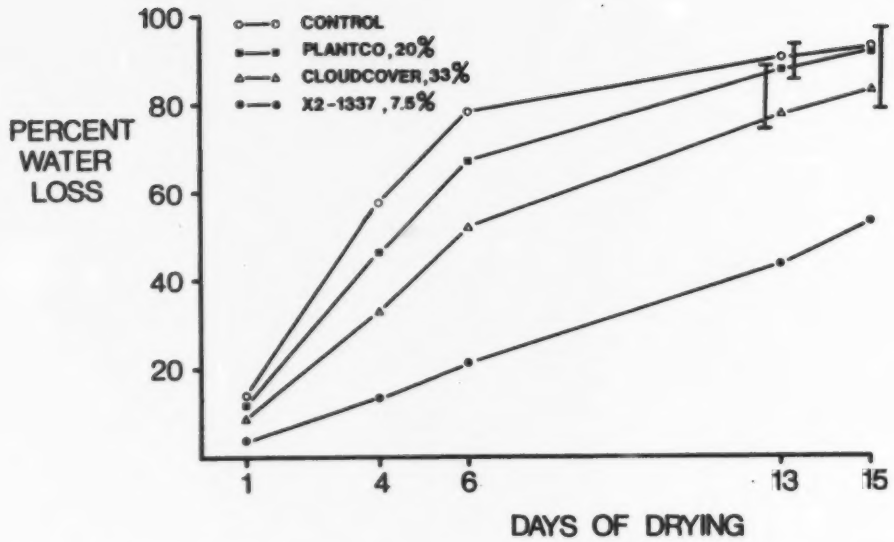

Figure 1. Water loss from black spruce container seedlings treated with PLANTCO, Cloudcover and X2-1337. Points bracketed by vertical lines do not differ significantly ($P<0.05$).

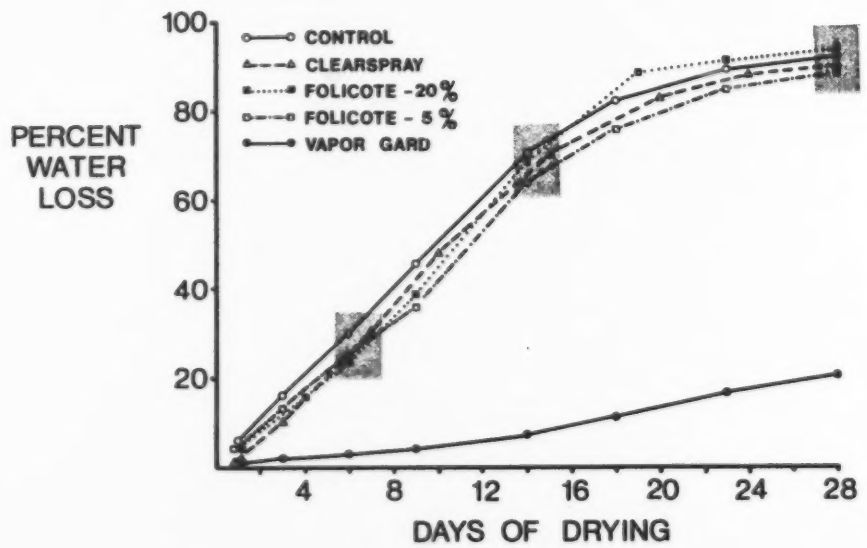

Figure 2. Water loss from black spruce container seedlings treated with Clearspray, Vapor Gard and two concentrations of Folicote. Points on days 6, 14 and 28 within shaded areas do not differ significantly ($P<0.05$).

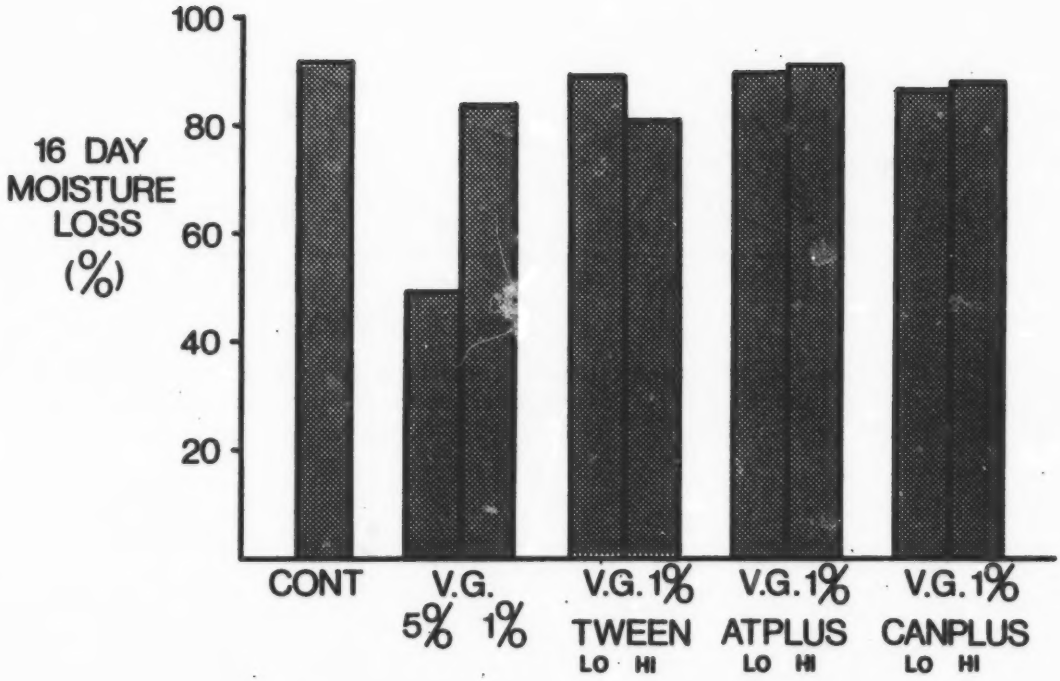

Figure 3. Water loss from black spruce container seedlings treated with Vapor Gard and combined with three different surfactants at two concentrations (0.15% and 0.50%). Only Vapor Gard at 5% significantly reduced water loss ($P<0.05$).

CONTAINER STOCK SHIPPING SYSTEM - NORTHERN REGION

B.K. Whelan
Senior Technician
Container Operations Co-ordinator
Ministry of Natural Resources
Northern Region

Shipping Systems

According to FMA agreements the Crown is responsible for delivering trees and placing the trees on the ground. So a handling system for trays had to be developed. The system presently in place is a summary of the choices of the 6 Districts in this Region.

Some options were to own everything, example: 15 dry freight vans, but privatization directives, maintenance, etc. discouraged this. Costs were a major item. We presently have the least number of units we can have for shipping and we have $300,000 invested in equipment and tenders are out for more, approximately $17,000 this fall.

These costs include 3 items: shipping frames, off-loaders and tray storage pallets.

Item I - Shipping Frames

These each hold 24 paper pot trays, approximately 6500 trees. We presently have 630 shipping frames. One dry weight van holds 26 of them. Each grower has either 2 sets or 3 sets of shipping frames.

The gutter-connected or 2 crop per year complexes have 3 sets, the single crop growers have 2 sets. This is to allow for one set being stacked at growers site while the other set is still in transit. The sets come back from the planting site the same day to the same grower, or to another grower depending on demand by field staff. The sets are shipped in freight

vans which are leased annually by M.N.R. for a 4-5 month period. The tractors are tendered separately so the trailers can be packed at the growers and loaded ahead of time. The tractor operators go early in the morning 2-3 A.M. and pick up in time for delivery first thing in the morning 6-7 or 8 A.M. depending on field demand. We prefer to deliver first thing in the morning, when people are not scattered all over the planting site, etc. The field staff at each district meet the trucks and guide them to the planting site, unload the trays out of the shipping frames and re-load empties into the van. If frames were left on site, we would need a lot more frames at $250.00 each, plus we would double our shipping cost. In 1984 cost for tractor rental van was 89c/km, a total of $167.000 dollars. The 1983 costs are shown in Tables 2 and 3 and 1984 shipping crop totals for each grower are in Table 4. With the shipping handled by one unit for the Region, all variables can be considered, we attempt to balance daily the demand with the supply.

Item II - Off-Loaders

These are independent hydraulic systems, powered electrically by the tractor batteries. We have 13 units at a cost of $7500.00 each. The units are put into the vans in the spring and removed in early August.

We unload the shipping frames, and split them in half by down stacking the two tier frames. This is to comply with labour laws of handling 30-40 pounds trays higher than a man's head.

Some bugs still have to be worked out but generally speaking the system is operational. Problems arise continually, but are curable. (Example: truckers not adhering to tender specifications for having correct size batteries to power the off-loaders.)

Item III - Tray Storage Pallets - (TSPs)

In the transportation system are the tray storage pallets. These have two purposes: 1) to store and stack empty trays after planting plus provide accurate inventory, 2) to store trays at the grower's complex in order to improve equipment handling.

Our intention is to take the T.S. pallets in February, after current crop growers have emptied them, to the District Office or FMA camps in early spring. The trays from the overwintered crops, planted in May, can be placed in the empty pallets. Then in mid-May and mid-June when the single-crop grower's crop, plus double-crop grower's second crop is seeded, we take the empty pallets to the District Offices or FMA camps in which the empty trays of the current crop can be placed from mid-June and onwards.

Tray Storage Pallet Movements

January	#1	Full TSPs are unloaded and seeded with '85 current at double-crop complexes.
February		Seeding continues.
March		Ship empty TSPs from #1 to District Offices (D.O.) or FMA camps. Field then reload TSPs in May or when planting starts with trays they planted from '84 overwintered crops.
April	#2	Late April and May, in '85, single-crop growers unload TSPs and seed their '85 overwintered crop which is to be planted in 1986. Empty TSPs go to D.O. & FMA camps for refilling by field staff with trays from the balance of '84 overwintered camps.
June	#3	All TSPs are unloaded at double-crop growers, who seed their second crop which is overwintered. Empty TSPs are taken to D.O. & FMA camps for field staff to load trays from #1 or the '85 current crop seeded at the double-crop growers in January and shipped after June 15.
August		TSPs, after trays being inventoried at field sites, are then returned to growers who inventory trays again.
		If District or FMA lose trays in the bush they pay. Broken trays are returned.

The M.N.R. owns the trays, therefore trays from one grower do not necessarily have to go back to him. This makes tray return more economical

and practical when you balance the number of trays in field stations with number of trays required by the 11 growers. We presently have 215,000 trays valued at $3 tray, a total of $645,000, and life expectancy of a tray is about 6 years. If we have colour-coded trays for each grower we would have 12 colours plus the field staff receiving trays from two or more growers would have to double their efforts.

To separate different colours in the field, plus the return shipping, would increase costs considerably.

In the item III these are the TSPs, not the trays, and we have 285 units at $250 each.

The equipment on hand is worth $300,000, plus we have $645,000 in trays, also the Crown supplies snow fence, the snow fence supports 1" x 10" boards and 3" x 4' x 16' beams for overwintering crops. The value of this is around $110,000. The overwintering material we consider to be written off during the life of the contract. The snow fence supports will last much longer because they are steel.

For the shipping operations we have an Apple III and programs worked up to aid us. Seasonal staff include a dispatcher and a maintenance man.

Appendix 1

AGENDA

Monday, June 18, 1984

7:00 - 10:00 p.m.	Registration at Bon Air Motel Ice Breaker (Cash Bar)

Tuesday, June 19

8:00 - 9:00 a.m.	Registration (cont.)
9:00 - 9:40 a.m.	Opening remarks ..... Cliff Emblin, District Manager Kirkland Lake District
	.. Trevor Isherwood, Regional Forester Northern Region
	.. Lou Forcier, Station Superintendent Swastika Forest Station
9:40 - 9:50 a.m.	Agenda and announcements ..... Richard Cameron Nurserymen's Meeting Co-ordinator Swastika Forest Station
9:50 - 10.10 a.m.	Coffee break
10:10 - 10:45 a.m.	Production of Containers in Northern Region ..... Ron Reffle Regional Container Stock Superintendent, Northern Region
10:45 - 11:15 a.m.	Northern Forest and Development Group ..... Bill Raitanen Co-ordinator N.F.D.G. Northrn Region
11:15 - 12:00 a.m.	Root Wrenching and Root Pruning ..... Bill Bunting Nu-Tech Services Orono, Ontario
12:00 - 1:15 p.m.	Lunch break
1:15 - 1:30 p.m.	Overview of Stock - Production Research Group ..... Chris Glerum Research Scientist Maple, Ontario
1:30 - 2:00 p.m.	Various Aspects of Overwintering in Container Stock Production ..... Steve Colombo Research Scientist Maple, Ontario
2:00 - 2:30 p.m.	Results of Bareroot Overwinter Storage Trials ..... Gerry Racey Research Biometrician Maple, Ontario

2:30 - 3:00 p.m.	The Multiple Leadering Problem ..... John Paterson, Research Assistant, Maple, Ontario
3:00 - 3:20 p.m.	Coffee break
3:20 - 4:30 p.m.	Panel Discussion on Root Pruning - Opening Statement ..... Chris Glerum, Research Scientist, Maple, Ontario On Root Soaking ..... Bob Hutchison, Research Assistant, Midhurst, Ontario Plant Moisture Stress (PMS) ..... Steve Colombo, Research Scientist, Maple, Ontario Culling Practices - who needs them? - who wants them? ..... John Paterson, Research Assistant, Maple, Ontario RAI and RV (Root Volume) in practice ..... Gerry Racey, Research Biometrician, Maple, Ontario
4:30 p.m.	Bus leaves Bon Air for Provincial Park
10:00 p.m.	Bus returns to Bon Air

Wednesday, June 20

8:30 a.m.	Bus leaves Bon Air
9:15 - 10:00 a.m.	Stop at Experimental Area en route to Nursery
10:00 - 10:20 a.m.	Coffee break
10:20 - 10:40 a.m.	Equipment Demonstration ..... Bob Day, Professor of Forestry, Lakehead University
10:40 - 11:10 a.m.	Tour of Nursery Facilities and Equipment
11:10 - 12:00 Noon	Tour of Greenhouses
12:00 - 1:15 p.m.	Lunch break
1:15 - 4:00 p.m.	Tour of Nursery Fields
4:00 p.m.	Bus leaves Nursery for Bon Air
7:30 - 9:30 p.m.	Informal Session and Trade Exhibit ..... Gilbert Leveille, Clonal Forestry Technician, Swastika Forest Station ..... Randy Morrison, Nursery Technician, Swastika Forest Station

Thursday, June 21

8:30 - 10:30 a.m.	Soil Management Panel	Vic Timmer Professor of Forestry University of Toronto
	.....	Helmut Krause Professor of Forestry University of New Brunswick
	.....	Bob van den Driessche Senior Tree Physiologist Research Branch Victoria, British Columbia
10:30 - 10:50 a.m.	Coffee break	
10:50 - 11:35 a.m.	Morphological and Physiological Quality of Nursery Stock in Relation to Outplanting Performance	Bob Day Professor of Forestry Lakehead University
11:35 - 12:00 Noon	Computer Committee Report	Ken Reese Nursery Superintendent Midhurst Nursery
12:00 - 1:15 p.m.	Lunch break	
1:15 - 2:00 p.m.	Castle & Cook Containers	Bob Klapprat Nursery Superintendent Thunder Bay Nursery
2:00 - 2:45 p.m.	Quality Control in Tree Planting and its Effect on Survival	Rob Galloway Unit Forester Englehart Management Unit
2:45 - 3:15 p.m.	Coffee break	
3:15 - 4:00 p.m.	Mechanization Committee Report	Mark Campbell Operations Supervisor Dryden Nursery

Appendix 2

ATTENDANCE

Name	Location
ARMSTRONG, Guy	University of Toronto
BARTY, Brenda	Swastika Forest Station
BOUFFORD, Don	Orono Nursery
BUNTING, Bill	Nu-Tech Services, Box 424, Orono
CALVERT, Ron	Timmins Sub-Regional
CAMERON, Richard	Swastika Forest Station
CAMPBELL, Alf	Kemptville Nursery
CAMPBELL, Mark	Dryden Nursery
CARLETON, John	Chapleau Nursery
COLOMBO, Steve	Maple, O.T.I.F.B.I.
CONNELL, Glenn	Thessalon Nursery
CONNER, John	Lakehead University, Thunder Bay
CRAWFORD, Randy	Midhurst Nursery
CREASEY, Kim	Ontario Tree Seed Plant, Angus
CRITCH, Mel	Midhurst Nursery
DAVIES, Gary	Thunder Bay Nursery
DAVIS, Wanda	Swastika Forest Station
DAY, Bob	Lakehead University, Thunder Bay
DINTER, Marie	Swastika Forest Station
ENSING, John	University of Guelph
FITZGERALD, Roy	Kemptville Nursery
FORCIER, Lou	Swastika Forest Station
FOLK, Ray	University of Toronto
GALLOWAY, Rob	Kirkland Lake District
GILLHAM, John	Chapleau Nursery
GLERUM, Chris	Forest Research, Maple
GOWER, Bill	Gogama Nursery
HUTCHISON, Bob	Midhurst Research Unit
ISHERWOOD, Trevor	Timmins Sub-Regional
SCOTT, Jarvis	Swastika Forest Station

KING, George	Plant Products
KLAPPRAT, Bob	Thunder Bay Nursery
KRAUSE, Helmut H.	University of New Brunswick
LEFFERS, Erin	Swastika Forest Station
LEPAGE, Richard	Swastika Forest Station
LEVEILLE, Gilbert	Swastika Forest Station
MCMILLAN, Doug	Swastika Forest Station
MACNAUGHTAN, David	Kemptville Nursery
MAHONEN, Clave	Swastika Forest Station
MANSFIELD, Carl	Midhurst Nursery
MASON, Chuck	Gogama Nursery
MOORE, Dave	Orono Nursery
MORRISON, Randy	Swastika Forest Station
MUNSON, Alison	University of Toronto
MYLAND, Terry	Dryden Nursery
NENICKA, Chris	Swastika Forest Station
NIEMI, Onervo	Swastika Forest Station
ODLUM, Kerry	O.T.I.F.B.I., Maple
ORR, Alf	Thunder Bay Nursery
PARTON, John	University of Toronto
PATCHELL, Ed	Thunder Bay Nursery
PATERSON, John	O.T.I.F.B.I., Maple
PFEFFER, Lloyd	Orono Nursery
RACEY, Gerry	Midhurst Research Unit
RAITANEN, Bill	Timmins Sub-Regional
RAITANEN, Elizabeth	Kemptville Nursery
REESE, Ken	Midhurst Nursery
REFFLE, Ron	Main Office - Toronto
REID, Jim	Thunder Bay Nursery
ROBERTSON, Don	St. Williams Nursery
RUTTAN, Arlene	Swastika Forest Station
SADREIKA, Vic	Main Office - Toronto
SCARRATT, John B.	Canadian Forestry Service, S.S.M.
SCHUESSLER, Peter	Swastika Forest Station
SECORD, John	Gogama Nursery

SEWELL, July	Thessalon Nursery
SMITH, Pamela	Kemptville Nursery
SWAILE, Brian	Tree Seed Plant - Angus
TIEMANN, Henry	Main Office - Toronto
TIMMER, Vic	University of Toronto
THOMPSON, Brian	Kirkland Lake District
TOWNSEND, Ernie	Swastika Forest Station
VAN DEN DRIESSCHE, Bob	British Columbia
VON ALTHEN, Fred	Canadian Forestry Service
WAYWELL, Charles	University of Guelph
WEBB, Paul	Canadian Forestry Service
WHELAN, Brian	Kirkland Lake District
WINTERS, John	O.T.I.F.B.I., Maple
WRAY, David	Algonquin Region
ZDRAZIL, Zdenek	Canadian Forestry Service, Petawawa